EFFECTS NON-PROTEIN NITROGEN, LACTOBACILLUS INOCULANT, AND SILO TYPE ON FERMENTATION AND NUTRITIVE VALUE OF FORAGE SORGHUM SILAGES

by

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INTRODUCTION

Forage sorghum is an important silage crop in the High Plains for growing cattle. Improved hybrid forage sorghum varieties are able to produce comparable dry matter yields with less fertilizer and moisture than corn (Heath et al., 1976 and Kanemasu, 1977). Harvesting of low dry matter silages increases the potential for clostridial-type fermentation and reduced feed intake. Researchers have investigated bacterial inoculation as a possible means to alleviate these problems. Although research data evaluating commercial inoculants for forage sorghum have not always indicated improvements in silage quality, several trials have shown improved cattle weight gains and feed conversions and silage dry matter recoveries (Brethour, 1978b, 1979, 1980; Bolsen and Ilg, 1981b). Non-protein nitrogen additions to low protein forages and crops have been used to enrich the protein content of the resulting silages. Recent data show reduced cattle weight gains and feed conversions (Brethour, 1974, 1976; Bolsen et al., 1981a) and decreased silage dry matter recoveries with non-protein nitrogen additions to forage sorghum and whole-plant corn silages (Bolsen et al., 1981a and Bolsen and Ilg, 1981b).

Mo and Fyrileiv (1979) reviewed the types of silos used in silage research and divided them into three main types: farm-scale, pilot-scale, and laboratory or miniature. Each type of silo has distinct advantages and disadvantages but only limited research has compared silo types and determined their effect on silage fermentation and nutritive value (Wilson and Wilkins, 1972; El Hag et al., 1979; Hingston and Christensen, 1982). Recently, nylon bag and 20 l polyethylene container laboratory silos were developed and compared with farm-scale silos (Bolsen et al., 1981a and Hinds et al., 1982b). The buried nylon bag was intended to simulate the conditions in the farm-scale silo, excluding that portion of the ensiled mass in contact

with the silo's exterior walls, doors, or exposed surfaces. Research advantages of the 20 l container over the farm-scale silo include: more treatments can be studied, treatments can be replicated several times and with more precision, smaller amounts of crop are required, the entire contents of the silo can be sampled, and the silos can be opened at various time intervals (McDonald, 1981).

The objectives of this investigation were to evaluate non-protein nitrogen and live bacterial inoculant additives on the rate and extent of fermentation, aerobic stability, and feeding values of forage sorghum silage for cattle and lambs; and to compare farm-scale stave silos with nylon bag and polyethylene container experimental silos.

LITERATURE REVIEW

A. Morphological Development of the Sorghum Plant

The first 30-35 days after the plant emerges, nearly all growth is foliar. Then the culm initiates rapid growth, and leaves and culm continue growing until maximum culm weight, at about 65 days. The following discussion defines each stage of growth as described by Vanderlip (1979).

The "emergence" stage of the sorghum seedling occurs when the cotyledons first break through the soil surface, usually within 3 to 10 days after planting. The next stage is the "three-leaf" stage which generally occurs about 10 days after emergence. The growing point of the seedling is still below the surface.

Following the three-leaf stage, the plant enters a period of rapid root development known as the "five-leaf" stage. This period occurs approximately 3 weeks after emergence. The seedling will have five fully expanded leaves and start a period of rapid nutrient uptake which continues until the plant is mature.

After about 30 to 35 days of growth, the growing point changes from vegetative to reproductive. This stage is known as "growing point differentiation". The plant will have seven to 10 fully developed leaves and may have lost the lower one to three leaves. From the time of planting to growing point differentiation generally is about one-third of the time from planting to physiological maturity. At this point, only 5% of the total growth has occurred; however, the plant has taken up 10 to 15 % of the nutrients it will use the entire season.

Following the growing point differentiation stage, rapid culm elongation and rapid leaf development occur simultaneously until the flag leaf is visible in the whorl. By then all except the final three to four leaves are fully expanded and the lower two to five leaves have been lost.

The "boot" stage is reached when all leaves are fully expanded, providing maximum leaf area and light interception. The potential head size has been determined. Boot stage occurs 30 to 35 days after the growing point differentiation stage.

Following the boot stage the peduncle grows rapidly extending the head through the flag-leaf sheath. "Half-bloom" stage is usually defined when one-half of the plants in the field are in some stage of bloom. The time of planting to half-bloom, depends on the maturity of the hybrid and environmental conditions; however, it usually represents two-thirds of the time from planting to physiological maturity.

"Dough" stage occurs when approximately three-fourths of the grain dry weight has accumulated. Lower leaves are still being lost with eight to 12 functional leaves remaining; nutrient uptake is essentially complete.

In the "physiological mature" stage, the maximum total dry weight of the plant has occurred. Grain moisture will be between 25 to 40 percent. After physiological maturity, the remaining functional leaves may stay green or die and brown rapidly.

B. Silage Fermentation

Silage is the result of anaerobic fermentation which produces sufficient concentration of predominately lactic acid to inhibit futher microbial activity. The main objective of silage fermentation is to preserve the crop with a minimum loss of nutrients and obtain a feed of high nutritive value for the animal. To accomplish this objective, there are two essential items according to McCullough (1977): 1) achieving and maintaining anaerobic conditions and there by inhibiting the wasteful activites of aerobic microorganisms and oxidative enzymes and 2) inhibiting protein destruction by clostridia under anaerobic conditions.

McDonald and Edwards (1976) listed five primary factors affecting the type, extent, and success of silage fermentation: 1) moisture content of the

forage, 2) buffer capacity of the forage, 3) availability of water soluble carbohydrates (WSC), 4) type of bacteria which predominate, and 5) speed of the fermentation.

An ideal fermentation should occur when a forage is ensiled with a dry matter (DM) content of 28 to 34 %, WSC content of 6 to 8 % of the DM, minimum buffering capacity of less than 450 mE per kg of the DM, and a temperature and degree of compaction suitable for an immediate bacterial population explosion (McCullough, 1977 and McDonald, 1981). Under such conditions most of the available carbohydrates would be converted to lactic acid with a minimum loss of dry matter and energy (McDonald, 1981). The formation of two moles of lactic acid from one mole of glucose results in a loss of about 3.1% of the energy.

The ensiling process consists of five phases as described by numerous authors.

Phase I. When the crop or forage is swathed or harvested, the plant is alive and actively respiring and this can continue for upto 3 to 4 days. At the same time, the ruptured plant cells nourish the aerobic bacteria causing a logarithmic increase in bacteria numbers as long as oxygen is available. Once the material is placed in a sealed silo, only a short period of time is required to consume the entrapped oxygen (Sprague, 1974). Plant enzymes and aerobic bacteria use the readily available carbohydrates to produce heat and carbon dioxide, thus decreasing the oxygen supply. Theoretically, with good compaction to exclude the air, the heat generated from respiration should only elevate the temperature about .83 C (Anonomous, 1980). The remaining temperature increase comes from aerobic bacteria which are converting plant sugars to carbon dioxide, water, and heat. Excessive oxygen entrapment during silo filling can result in initial ensiling temperatures of over 40 C. This reduces the chance of a desirable anaerobic fermentation and results in heat-damaged protein.

Phase II. Initiation of acetic acid production, which begins within hours after ensiling, is by facultative anaerobic bacteria which use the remaining oxygen. The acetic acid formation causes the pH to drop to a more favorable one for the lactic acid bacteria.

Phase III. Lactic acid producing bacteria are found in relatively small numbers on the growing forage (Stirling, 1953; Kroulik, 1955a; Nilsson and Nilsson, 1956; Stirling and Whittenbury, 1963; Henderson et al., 1972; Speckman et al., 1981). But once anaerobic conditions exist, these bacteria reproduce rapidly and act on readily available carbohydrates in the forage to produce lactic acid and some other organic acids (ie., acetic, propionic, formic, and succinic).

Phase IV. Lactic acid formation and microbial activity slow down gradually as the pH approaches 4.0. The ensiled mass is stabilized within 2 to 3 weeks. The decline in microbial activity also causes the temperature to decline slowly.

Phase V. The pH inhibits further microbial growth and enzyme action, thus preserving the mass. If during the anaerobic phase (Phase III) the pH decline was impaired, clostridial fermentation may occur. These butyric acid producing bacteria will attack both the remaining soluble carbohydrates and the lactic acid that has already accumulated. Production of butyric acid by the conversion of two moles of lactic acid to one mole of butyric acid, carbon dioxide, and hydrogen results in an energy loss of 22.1% if the lactic acid came from glucose. In addition, the breakdown of proteins with the formation of ammonia, carbon dioxide, and other compounds (ie., branched-chained VFA and amines) which results in the production of low-quality silage.

C. Silage Quality

Good silages are characterized as follows: 1) pH values of 4.2 to 4.5, or below. Low dry matter crops or forages require the final pH to be lower

for efficient silage conservation (Waldo, 1979). 2) Lactic acid content of 3 to 5 % of the dry matter. Corn and other grain-type silages will usually have higher lactic acid levels than forage-type silages. 3) Butyric acid content of .1% of the DM or less. Butyric acid results in high energy and dry matter losses which can be avoided. 4) Ammonia-nitrogen content should not exceed 5 to 8 % of the total nitrogen. 5) Temperatures during ensiling should not exceed 38 C. High temperatures result in browning (Mallard reaction) and denatured protein.

Many investigators have proposed indexes for silage quality. Breirem and Ulvesli (1960) suggested an index of a good silage fermentation based on pH; lactic, acetic, and butyric acids; and ammonia-nitrogen (table 1). Nilsson et al. (1956) as cited by McCullough (1978) used only butyric acid and ammonical nitrogen as indicators of silage quality (table 2). Of the

TABLE 1. Breirem and Ulvesli (1954) index for silage quality.

1) pH	Maximum 4.2
2) Lactic acid %	1.5 - 2.5
3) Acetic acid %	0.5 - 0.8
4) Butyric acid %	< .1
5) Ammonia-nitrogen in % of total N	< 5.0 - 8.0

TABLE 2. Nilsson et al. (1956) index for silage quality.

Quality	NH_3-N % of total N	Butyric acid
Very good	< 12.5	< .10
Good	12.6 - 15.0	.11 - .20
Medium	15.1 - 17.5	.21 - .30
Bad	17.6 - 20.0	.31 - .40
Very Bad	> 20.1	> .40

methods which have been proposed to classify silage fermentation, the key developed by Fleig (1938) as cited by McCullough (1978) has been the most widely used and best researched.

The Fleig values were improved by the Study Group for Feed Testing in West Germany in 1966 (table 3). The values listed are the ones suggested by Zimmer (1966) as cited by McCullough (1978) for that re-evaluation. The primary changes in the Flieg key were to use the acids as their percentage of the total acids and to use a system of points based on these percentages. Although the original Fleig values were based on steam-distillation method for determining the acids, the Study Group concluded that there should be no difficulty in using other methods to determine the acids. The index is calculated by determining the percent of lactic, acetic, and butyric acid in the silage.

D. Silage: A Method of Crop Conservation

Silage production in 1981 exceeded 10 million tons in Kansas. Some advantages for silage as a method of conserving crops and forages are: 1) Improved cropping practices--silage increases the potential of double and even triple cropping as a means of effectively using land and capital resources. 2) Reduced weather damage at harvest--Zimmer (1977) combined years of research data to illustrate the effects of weather and harvesting methods on field losses (figure 1). He noted that as the DM content had to increase due to method of harvesting, the amount of dry matter lost in the field also increased. Green-chop and silage systems had the lowest field losses due to weather. 3) Total mechanization--the ability to totally mechanize the entire harvesting, storing, and feeding operation is enhance with silage over that of the cereal grains or even some hay systems, thus a saving on additional hired labor. 4) Harvesting maximum nutrients per land unit--for grain crops, such as corn or sorghum, harvesting only the grain leaves 50% or more of the available nutrients to ruminants in the field.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

TABLE 3. New version of Flieg Key.

Item	Percent of total acids calculated from weight percentages	Fleig Points
Lactic acid	0 - 20.0	0
	20.1 - 25.0	0
	25.1 - 30.0	2
	30.1 - 34.0	4
	34.1 - 38.0	6
	38.1 - 42.0	8
	42.1 - 46.0	10
	46.1 - 50.0	12
	50.1 - 54.0	14
	54.1 - 58.0	16
	58.1 - 62.0	18
	62.1 - 66.0	20
	66.1 - 70.0	24
	70.1 - 75.0	28
	> 75.0	30
Acetic acid	0 - 15.0	20
	15.1 - 20.0	18
	20.1 - 24.0	16
	24.1 - 28.0	13
	28.1 - 32.0	10
	32.1 - 36.0	7
	36.1 - 40.0	4
	40.1 - 45.0	2
	> 45.0	0
Butyric acid	0 - 1.5	50
	1.6 - 3.0	30
	3.1 - 4.0	20
	4.1 - 6.0	15
	6.1 - 8.0	10
	8.1 - 10.0	9
	10.1 - 12.0	8
	12.1 - 14.0	7
	14.1 - 16.0	6
	16.1 - 18.0	4
	18.1 - 20.0	2
	20.1 - 30.0	0
	30.1 - 40.0	- 5
	> 40.0	-10

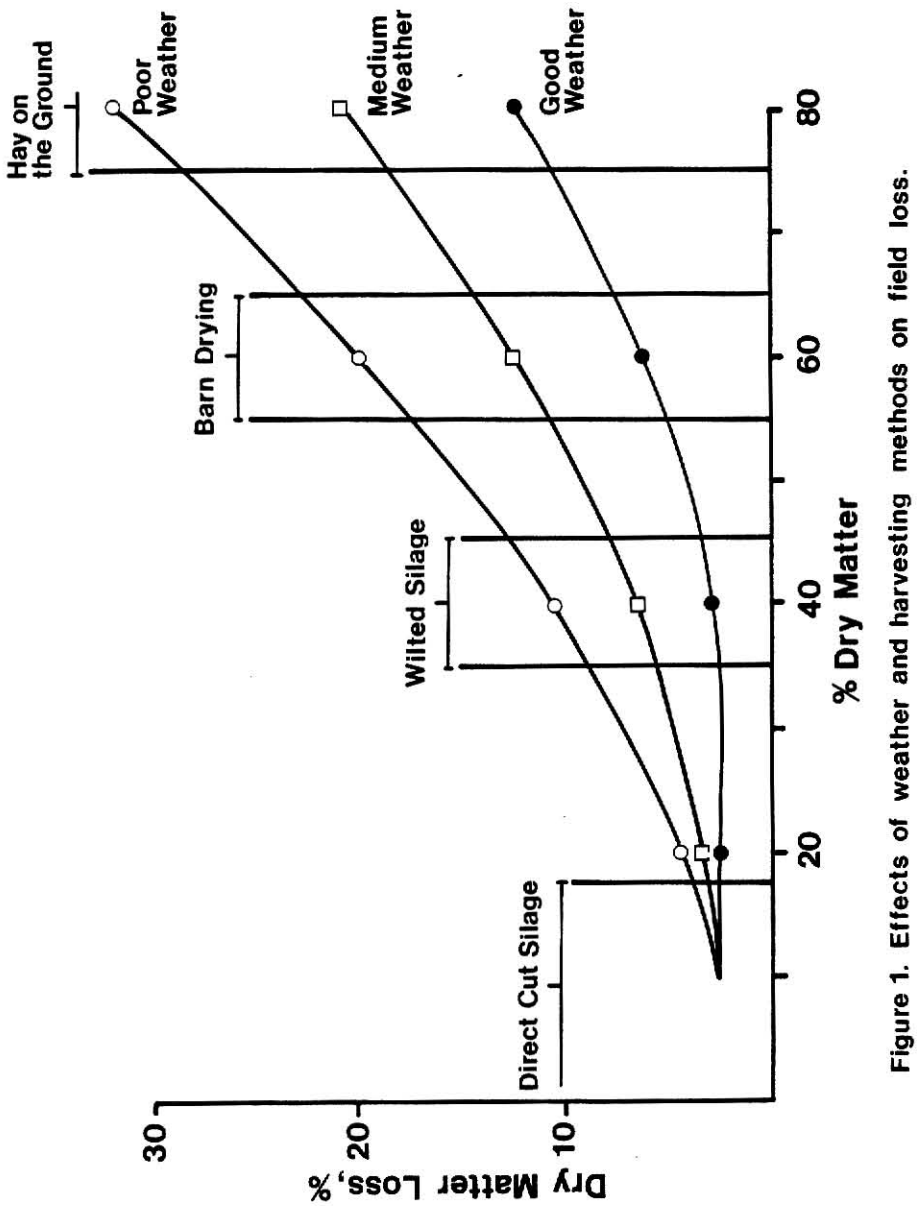

Figure 1. Effects of weather and harvesting methods on field loss.

Harvesting the whole plant provides a roughage source for the diet and the ability to harvest the plant at maximum digestiblity (table 4, 5, 6). 5) Improved feeding program--increasingly livestock producers are formulating rations based on chemical composition of ingredients. Silage can provide a long-term source of feed of uniform composition, thus removing weekly and monthly variations in feedstuffs.

TABLE 4. Harvest schedule for legumes and grasses.

Crop	First cutting	Second and latter cuttings
Alfalfa		
Established stands	Full bud to early bloom	Early bloom
First-year harvest	Early to mid-bloom	Early bloom
Stands to be plowed down	Early to full bud	Full bud
Birdsfoot trefoil	Early bloom	1/2 to full bloom
Red clover		
Established stands	1/4 to 1/2 bloom	1/2 bloom
Spring seeding	Before full bloom	6 weeks after first cutting
Alsike and ladino clovers	1/4 to 1/2 bloom	1/2 bloom
Crownvetch	1/10 to 1/4 bloom	1/10 to 1/4 bloom
Perennial grasses	Heads emerging from boot	6 to 7 weeks after first cutting
Summer annual grasses	Before heads emerge	
Cereal grains	Soft-dough stage	
Corn	Full dent stage	
Sorghum	Soft-dough stage	

TABLE 5. Influence of stage of maturity on nutritive content of first cutting legumes.

Approximate harvest date	Stage of maturity	-----Dry matter basis---- % Dig. protein	% TDN
May 15	Vegetative	24	70
May 30	Bud	20	63
June 15	Bloom	15	56
June 30	Mature	11	49

TABLE 6. Effects of stage of maturity on the nutritive content of corn silage.

Stage	% Dig. protein	% TDN
Pre-silk, 10 days	8	61
Silk	7	63
Milk	3	66
Dent	4	69
Over-ripe	-	60

Silage as a method of conserving crops and forages is not without disadvantages: 1) Silage does not move in the normal market channels, thus making it difficult to establish a value for silage. 2) Silage possesses considerably more moisture than air-dry feeds, thus increasing the cost of handling and transportion. 3) Silage requires efficient management. Under poor management 30 to 50 % of the dry matter and 10 to 30 % of the gross energy in silage can be lost before it is consumed by an animal (Zimmer, 1979). 4) Silage has a relatively short shelf-life once removed from the silo.

E. Aerobic Deterioration in Silage

The importance of achieving and maintaining anaerobic conditions during the ensiling period has been mentioned previously. Ideally, the process of making silage should be one of expediency, but the harvesting and immediate ensiling of a forage in an air-excluding environment seldom occurs. In practice, the crop or forage often must be wilted prior to ensiling or large silos hinder rapid filling which can result in several days or weeks before the silo can be effectively sealed. Aerobic activity can occur during four stages of silage production.

Stage I occurs prior to harvest. During field wilting, microbial activity is in a dynamic state. The lactic acid bacteria population is usually small (Stirling, 1953; Kroulik, 1955a; Nilsson and Nilsson, 1956;

Stirling and Whittenbury, 1963; Henderson et al., 1972; Speckman et al., 1981) but these facultative anaerobes can multiply rapidly in the presence of oxygen if the forage material has been damaged and the plant juices have been released (Kroulik 1955a; Stirling and Whittenbury, 1963; Henderson et al., 1972). The majority of the epiphytic bacteria on the fresh forage are, however, strict aerobes (Kroulik, 1955b and Whittenbury, 1961) and these can be expected to multiply with the extent depending upon the degree of laceration or bruising of the crop and the duration of wilting. There is some evidence that the yeast population increases during wilting (Kroulik, 1955a) and this may have an adverse effect on the stability of the silage once removed from the silo (Honig and Woolford, 1979).

Stage II is of relatively short duration if the forage has been ensiled properly (rapid filling and sealing). Entrapped atmospheric oxygen that enters the silo along with the forage is used up very rapidly by plant respiration (Sprague, 1974). Sprague measured the oxygen disappearance in large (2 m diameter) plastic silos filled with alfalfa under field conditions and found that 90% of the oxygen was lost within 15 minutes and less than .5% remained after 30 minutes from the time of sealing the silos.

If filling the silo is slow and sealing is delayed (Stage III), the oxygen entrapped is allowed to penetrate the fresh forage and maintain or increase the oxygen influence on fermentation. On a laboratory-scale, Yoder et al. (1960) demonstrated that a delay of 12 hours in sealing alfalfa in plastic laboratory silos effectively converted a lactic acid fermentation to one of butyric acid. Miller et al. (1961) carried out an experiment on a field-scale, ensiling a mixture of Italian ryegrass and crimson clover either within 6 hours of harvest with packing the surface or over 7 days without packing the surface. They found a significant reduction in silage quality, nutritive value, and animal performance in the latter treatment. Similar observations have been made by Lancaster and McNaughton (1961). These

results were partly explained by the experiment of Kearney and Kennedy (1962). Chopped forage was allowed to stand in a moist atmosphere in small mesh bags for up to 30 hours and samples were removed and ensiled in glass jars every 6 hours. The samples showed a reduction in WSC content of up to 50% before they were ensiled, which resulted in reduced lactic acid and increased butyric acid content in the silages. Brown and Kerr (1965) demonstrated the magnitude of losses which can occur if sealing is omitted entirely on 30 ton trench silos. Forage ensiled at 50% DM in unsealed silos gave losses of feedable dry matter of 69.5 to 71.1 % compared with 10.5 to 11.3 % losses in sealed silos.

Secondary aerobic deterioration (Stage IV) begins when the silo is opened and the silage is exposed to air during feeding. The anaerobic environment of the silage is changed to an aerobic one. The newly created aerobic conditions give the once dormant aerobic bacteria a chance to multiply resulting in additional deterioration of the silage. Silage particularly prone to deterioration are made from carbohydrate rich forages, those retaining high levels of residual WSC resulting from chemically restricted fermentation or heavy wilting (Ruxton et al., 1975).

The importance of yeasts in aerobic deterioration was first reported by Beck and Gross (1964). They demonstrated that silages with a high population of yeasts were more unstable on exposure to air than silages with low populations. The role of yeasts was confirmed by Daniel et al. (1970) who showed that silages with yeast populations of more than 10^5 organisms/g were susceptible to deterioration. After initiation by yeasts, a second microflora is builtup consisting of proteolytic bacteria, streptomycetes, and molds (Beck, 1978). This is often reflected by the appearance of two distinct thermal peaks during deterioration.

F. Silage Additives: General

Within the past 20 years the silage community has turned to the use of "silage aids" to reduce aerobic deterioration, improve feeding value, and increase the conservation of nutrients in silage. McCullough (1977) listed four broad categories of silage aids which can alter silage fermentation.

1. Direct Acidification. The concept of direct acidification is the rapid drop in pH and preservation of the ensiled forage. The applied acid replaces the acid normally produced during fermentation, producing silages with minimal fermentation losses. Some examples of acids are sulfuric, hydrochloric, formic, propionic, and citric.

2. Aids to Acidification. The basic idea is to increase the rate and efficiency of the fermentation, thus retain more of the nutrients in the ensiled forage. There are essentially two ways of accomplishing this. The first is by adding lactic acid producing microorganism which insures that sufficient numbers will be available for a rapid fermentation. The other is to add enzymes which break down plant materials (cell wall constituents) into readily fermentable carbohydrate sources for the lactic acid producing microorganism. The latter way assumes that there are sufficient microorganism but the availablility of nutrients may be limiting the fermentation.

3. Preservatives. In theory, there exist compounds which can be added to a forage to inhibit all chemical and biological reactions, thus preserving the forage in its original condition. Examples of materials used are sulfur dioxide, sodium metabisulfite, formaldehyde, antibiotics, and antioxidants.

4. Nutrient Additions. This is a straight forward way to theoretically improve the feeding value of the silage, and it involves the addition of feedstuffs to the forage at ensiling time. Included in the materials which have been used are molasses, citrus pulp, cereal grains, whey, non-protein nitrogen sources, limestone, and mineral mixes.

Groups within the "aids to acidification" and "nutrient addition" include inoculants and non-protein nitrogen additions, respectively. Inoculants are considered to be any live microbial culture addition and non-protein nitrogen additions would include ammonia, urea, and biuret. These two groups will be discussed in detail.

G. Silage Additives: Inoculants

It was believed until the early 1950's that forages had sufficient adherent bacteria for rapid acidification during the ensiling process. Stirling (1953) noted that relatively few of the bacteria present on grasses or legumes had the ability to produce lactic acid. Other researchers (Kroulik, 1955a; Nilsson and Nilsson, 1956; and Stirling and Whittenbury, 1963; Henderson et al., 1972) have studied a variety of forages and substantiated Stirling's findings. Speckman et al. (1981) examined the bacterial population on the whole corn plant in 23 states in the USA and found that there were no geographical differences in bacterial populations. They found that 42% of the samples had populations below the countable limits (100/g) and 77% of the samples had counts below 2000/g.

Gross (1969) and Gross and Riebe (1974) reported that the success of inoculation of fresh grass with selected strains of Lactobacillus plantarum was largely dependant on the number of cells applied to the plant material. An inoculation of 10^6 to 10^7 cells/g of forage resulted in good quality silage, while lower number of cells/g did not prevent clostridial activity. These findings were confirmed by Beck (1965) who used lyophilized preparations of L. plantarum found that 10^6 cells/g applied to grass or alfalfa usually produced good quality silages.

Because of the relative low numbers of lactic acid producing bacteria on fresh forages, inoculation with numerous bacteria has been evaluated by many researchers. Bacteria included L. plantarum, L. acidophilus, L. burgarius, L. brevis, Streptococcus lactis, S. cremoris, S. faecalis, Bacillus

subtillis, and Leuconostoc mesenteroides (Lesins and Schultz, 1968; Ohyama et al., 1975; Moon et al., 1979, 1980, 1981; Burghadi et al., 1980; Thonney et al., 1980; Ely et al., 1981; Moon and Ely, 1981).

The effects of silage inoculation have been inconsistant when evaluated by animal performance, silage digestibility, and silage fermentation characteristics. The inconsistency may result from the type of crop and its moisture content and bacteria species and strains present. Whittenbury (1961) has defined the criteria which a potential organism should satisfy for use in silage.

1. It must grow vigorously and be able to compete with, and preferably dominate, other organisms.

2. It must possess a homofermentative pathway in order to produce the maximum amount of lactic acid from readily available carbohydrates.

3. It must be acid tolerant and capable of producing a final pH of at least 4.0. Preferably it should be able to produce this low pH as rapidly as possible in order to inhibit the growth of other microorganisms.

4. It must be able to ferment glucose, fructose, sucrose, fructans, and, preferably, pentose sugars.

5. It must not produce dextran from sucrose or mannitol from fructose.

6. It should have no action on organic acids.

7. It should possess a growth temperature range extending to 50 C.

8. It should be able to grow in high dry matter materials (ie., wilted forages).

The ideas of Whittenbury were also shared by Lesins and Schultz (1968). They believed the best method for obtaining efficient inoculants would be to isolate bacteria from good-quality silage made from the same forage and under similar conditions to those where the inoculum was to be used.

Wieringa (1961) found Lactobacillus plantarum to be the only one of 81 strains isolated from silages to be particularly suited for fulfilling the

criteria set forth by Whittenbury. Ohyama et al. (1975) inoculated ryegrass (13.6% DM) and orchardgrass (16-22% DM) with a selected strain of L. plantarum plus glucose. They found that the inoculant, even when air was infused for the first 4 days, produced superior quality silage compared with the control silage according to the Fleig scores. The inoculated silages had higher lactobacillus counts and lactic acid concentrations; lower gram-negative bacteria counts and ammonia-nitrogen content; and had the fastest decline in pH staying below 4.2 after day 2.

Several other workers have evaluated L. plantarum on a variety of crops. Moon et al. (1980) used L. plantarum on alfalfa (second cutting, 10-30% bloom), corn (early dent), wheat (late bloom), and sorghum (early dough). The inoculant used was a liquid culture that was stored at -20 C. When compared to control silages, inoculated silages had higher concentration of lactic acid; and in alfalfa and wheat (but not in corn or sorghum) a more rapid pH decline and lower final pH. These results were highly correlated with increased lactobacillus populations in alfalfa and wheat inoculated silages, but not in corn silage which had increased lactobacillus counts without a more rapid pH decline. However, control and inoculated corn silages had very rapid pH declines which were below 3.5 after 2 days. Similar results with alfalfa and wheat were reported by Ely et al. (1980). They found that inoculated alfalfa (second cutting, 10-30% bloom) and wheat (late bloom) silages had lower final pH than the control silages. The alfalfa silage had improved crude protein recovery (95.6 vs. 82.6%). They also reported that the L. plantarum had no significant effects on corn (early dent) and sorghum (early dough).

O'Leary and Hemken (1980) inoculated corn silage (35% DM) with a frozen culture of L. plantarum. When compared to control silage, the inoculant resulted in higher lactobacillus populations during the first 3 days of fermentation, produced a slightly more rapid pH decline, and gave an ensiling

temperature that was cooler. The final control silage had almost twice as many clostidia bacteria but only one-sixth of the numbers of yeasts and molds compared with the inoculated silage. Because of the yeasts and mold numbers, the inoculated silage was less stable on exposure to air than the control.

Ely et al. (1981) studied the effects of a L. plantarum strain on alfalfa (second cutting, 20-40% bloom), wheat (early boot), corn (early dent), and sorghum (late dough). The inoculant increased the recovery of dry matter and crude protein in alfalfa silages but decreased the recovery of nitrogen-free extract in the wheat silages. In corn and sorghum silages, the inoculant showed no improvement in the already high nutrient recoveries. They also noted increased ($P<.05$) lactic acid content in inoculated alfalfa and wheat silages which agrees with previous data of Moon et al. (1980) and Ohyama et al. (1975). Inoculation significantly lowered pH of the alfalfa and wheat silages but did not affect the pH of the corn or sorghum silages. The lowered pH related to increased lactobacillus counts for the inoculated alfalfa and wheat silages, while inoculated sorghum silage had significantly higher counts but not a lower pH.

These data with L. plantarum suggest that a microbial inoculant may have some benefit, particularly if the adherent bacteria on the crop are not sufficient to produce a rapid pH decline in the silage. These results also indicate that alfalfa and wheat silages showed the greatest response to L. plantarum, while corn and sorghum silages show little, if any, response. The strains selected have been those which typically occur in silage, generally corn silage. This may partially explain why inoculants have given only slight responses with corn and similar crops (ie., sorghum). The addition of an inoculant, which already exist naturally on the crop, would not be beneficial to the ensiling process unless there are insufficient bacteria numbers.

Recently, numerous workers have evaluated other lactobacillus species (Moon et al., 1979 and Burghardi et al., 1980), genus of bacteria (Lesins and Schultz, 1968; Burghardi et al., 1980; Huber et al., 1981), and combinations of lactobacillus species and strains and genus of bacteria (Waldo and Goering, 1976; Brethour, 1977b, 1978a,b, 1979, 1980; Ely et al., 1979; Goering and Waldo, 1979; O'Leary et al., 1979, 1981; Moon et al., 1980, 1981; Bolsen et al., 1981a,b).

Burghardi et al. (1980) studied Lactobacillus bulgaricus, L. acidophilus, L. brevis, Streptococcus lactis, and S. cremoris at two levels ($4.5x10^7$ and $22.5x10^7$ live organisms/kg wet forage) on whole-plant corn (31-32% DM). Aspergillus oryzae was added at two levels, although the number of organisms were not counted. There were no effects ($P>.05$) of level or species added on silage dry matter content or dry matter recovery. Non-protein nitrogen (NPN) in the silage tended to increase with the level of inoculation, with the higher level of A. oryzae producing significantly higher NPN values than the lower level of inoculation. The ammonia-nitrogen contents were higher ($P<.05$) in silages inoculated with L. bulgaricus, S. lactis, and S. cremoris while the other inoculums tended to increase ammonia-nitrogen over the control. Huber et al. (1981) noted that Bacillus subtillus applied on alfalfa (46% DM) reduces ammonia-nitrogen accumulation. Burghardi et al. (1980) found that S. cremoris produced less ($P<.05$) lactic acid at the low level while the other inoculums produced similar concentrations as the control corn silage. Huber et al. (1981) reported increased lactic acid formation with no effect on final pH but a decrease in WSC from B. subtillis applied to wilted alfalfa (46% DM). Hall and Hopkins (Hall and Hopkins, unpublished data) used farm-scale bunker silos and noted an increase ($P<.05$) in lactic acid with L. acidophilus applied to grass (27-29% DM), but this was not found in the 30 kg laboratory silos.

Burghardi et al. (1980) noted that L. acidophilus and S. cremoris tended to decrease acetic acid production, while the other inoculums did not alter acetic acid production. It was also observed that the higher level of L. acidophilus decreased ($P<.05$) acetic acid concentration over the lower level.

Moon et al. (1979) reported that inoculation of wheat (early boot) decreased the pH more rapidly with a corresponding increase in lactobacilli and streptococci counts compared with the control. They also noted no microbiological or chemical effects from inoculating alfalfa (second cutting, 20-40% bloom) or corn (late dough). They did find that the silage microflora reached maximum bacterial populations on day 2 with the molds and yeasts counts generally decreasing.

Alfalfa and other legumes have attracted a lot of attention from the commercial inoculant industry. It has been well documented that alfalfa is a difficult forage to ensile, due to its high levels of protein, calcium, and magnesium which accounts for much of its high buffer capacity (McDonald, 1981). In addition, these forages contain low levels of water soluble carbohydrates. The concept for inoculants is to utilize the WSC as efficiently as possible for a rapid pH decline and to make more carbohydrates available by extra-cellular enzyme activity from the added yeasts and fungi. Results with commercial inoculants have been variable.

Carpintero et al. (1979) ensiling a ryegrass-clover mixture (19.9% DM) in laboratory-scale silos with an addition of an inoculant containing Lactobacillus plantarum, Leuconostoc mesenteroides, and Streptococcus faecalis (inoculant). Inoculated silage contained more lactic acid and less butyric acid and ammonia-nitrogen, indicating the absence of clostridial-type fermentation. The inoculated silage had a lower pH by day 4 and sustained it for the duration of the ensiling period, indicating a more rapid fermentation with the inoculant.

McDonald et al. (1964, 1965) worked with Italian ryegrass (15.6% DM), orchardgrass (13.9-14.2% DM), and red clover (14.2% DM). In 1964, they noted for inoculated orchardgrass silage that lactic acid increased, acetic and butyric acids decreased, and a reduction in pH. But for the Italian ryegrass they found no measurable differences with the addition of the inoculant. In 1965, they noted for inoculated silages a slight increase in lactic acid and a slight decrease in acetic acid but not enough change in concentrations to alter the pH.

Moon et al. (1981) evaluated the commercial inoculant, Sila-bac, which had Lactobacillus acidophilus as its primary lactic acid bacteria and they used alfalfa (second cutting, 20-40% bloom), wheat (early bloom), and corn (early dent). All inoculated silages had lower ($P<.05$) lactic acid concentrations. Alfalfa silages showed no change in acetic acid content from the inoculated silages, while wheat silages showed a decline and corn silages an increase in acetic acid content with inoculation. Both wheat and corn silages had an increase in butyric acid formation with the inoculant, but it should be noted that the wheat silages were of poor quality, regardless of treatment. The final silage pH values were not affected by inoculation nor were the rates of pH decline. Bolsen et al. (1980a) reported no effect on final pH but a reduction in lactic acid concentration and dry matter loss when alfalfa silage (34-37% DM) was treated with Sila-bac.

Rakshit and Voelker (1981) evaluated alfalfa and corn silages treated with Sila-max (Aspergillus oryzae, Bacillus subtillis, and lactic-acid starter culture) and Super Silage Treat (A. oryzae and Lactobacillus plantarum). They noted that both products reduced pH and dry matter loss; and increased lactic acid contents of the alfalfa and corn silages. Huber et al. (1981) found similar results when they studied alfalfa silage (46% DM).

El Hag et al. (1979) used alfalfa at two dry matter contents (28 and 56%) with inoculants and also evaluated the additions of lactose and lactose

plus inoculum on 28% DM alfalfa. They found no increase in lactic acid or titratable acidity when the inoculants were applied at the same dry matter content. The addition of lactose and lactose plus inoculum produced higher lactic acid levels and lower pH than the control but lactose plus inoculum was similar to lactose alone. Baker and Voelker (1958) investigated the addition of molasses and molasses plus inoculum on alfalfa (third cutting, 25-40% DM). They found both molasses and molasses plus inoculum dropped the pH faster and it remained lower than the pH of the control.

Ely et al. (1979) worked with Lactobacilli preparations on wheat (early boot), ryegrass, alfalfa (second cutting, 20-40% bloom), corn (late dent), and sorghum (late dough). They found no differences in silage composition or nutrient recoveries with Lactobacilli additions. O'Leary et al. (1979) evaluated two lactobacilli cultures on alfalfa, triticale, and corn silages (25-60% DM). They concluded that the inoculants did not improve silage fermentation. O'Leary et al. (1981) evaluated a mixed culture with corn (35% DM) and alfalfa (35% DM) silages in 19 l capacity experimental silos. The inoculated alfalfa had a faster fermentation, and after 2 days of ensiling, the inoculated alfalfa silage had a lower pH that the control. Ahrens et al. (1981) tested Sila-bac on an alfalfa-grass mixture and found that after 6 days the inoculated silage had a lower pH than the control but the final pH after 21 days were similar.

Whole-plant corn and sorghum are considered to be easy crops to ensile because of their low buffer capacities and high levels of carbohydrates, both starch and water soluble. The data with inoculants have generally shown only slight improvements in silage quality or no improvements at all. Buchanan-Smith and Yao (1981) evaluated Sila-bac with whole-plant corn silage using farm-scale silos. The additive did not significantly affect silage fermentation. In a second trial the authors used laboratory-scale silos to evaluate alfalfa ensiled at four dry matter levels (20, 30, 36.5, and 47.5%),

four levels of glucose (0, 4, 8, 12% of the DM), and three additives (no additive, Silozyme, and Silozyme-plus). They obtained significantly higher lactic acid levels overall with Silozyme-plus (Aspergillus niger and silage bacteria) compared with Silozyme (A. niger). The lactic acid values for all additive silages were not significantly different when compared with the control. There have been several reports in the literature in agreement with these data. Luther et al. (1982) and Thonney et al. (1980) reported no improvement in fermentation of whole-plant corn silage (40% DM) or alfalfa-timothy (45% DM) from the addition of commercial inoculant additives. Black et al. (1980) found that maturity and dry matter content both significantly affected the fermentation of sorghum silage but that four inoculant and (or) enzyme additives did not. Goering and Waldo (1979) used Sila-bac and found no significant differences in the fermentation patterns of corn (32% DM) or orchardgrass (20% DM) silages.

H. Silage Additives: Non-protein Nitrogen Additions

Non-protein nitrogen (NPN) additions have been accomplished in a number of ways to crops particularly low in crude protein (ie., corn and forage sorghum). These crops have been traditionally supplemented with natural protein and, to a lesser extent, with NPN at the time of feeding. Summarized in table 7 are performances of growing cattle fed silage rations supplemented with natural protein and non-protein nitrogen. Non-protein nitrogen supplements resulted in slower gains and poorer conversions of silage to weight gain.

Numerous researchers have investigated the addition of NPN to the crop at the time of ensiling. Results presented in table 8 show that urea added at the time of ensiling could be utilized as a source of supplemental nitrogen by growing cattle. The urea treated silages supported faster gains and better feed conversions than did the unsupplemented silages.

TABLE 7. Comparison of natural protein and NPN supplementation of silage growing diets at the time of feeding.[1]

Author	Year	ADG, kg		F/G	
		Natural protein	NPN	Natural protein	NPN
Brethour	1967	.54	.32	ND	ND
Woods and Tolman	1968	.88	.75	7.69	8.54
		.78	.69	8.81	9.87
Woods et al.	1968	.75	.67	6.74	7.66
Woods and Tolman	1969	.83	.76	7.92	8.15
Cash et al.	1971	.80[b]	.74[a]	9.88	10.25
Burghardi et al.	1980[2]	1.06	.98	6.97	7.37
Bolsen et al.	1980b	.97	.91	7.28[a]	8.21[b]
Bolsen and Ilg	1981b	1.11	1.04	7.70[a]	8.40[b]

[1]ND means not determined.
[2]Summary of 9 trials.
[a,b]$P<.05$.

TABLE 8. Comparison of urea treated corn silage with control silage without supplementation at the time of feeding.

Author	Year	Urea levels, %	Test cattle	ADG, kg		F/G	
				NPN	control	NPN	control
Meiske et al.	1968	.5	calves	.78	.53	6.74	8.94
Beattie et al.	1971	.6	steers	1.04[b]	.71[a]	7.94	9.63
Miller et al.	1979	1.0	steers	1.09[b]	.94[a]	6.63[a]	7.70[b]

[a,b] $P<.05$.

Data in tables 9 and 10 show comparisons of various NPN treated silages with control silages supplemented with NPN at the time of feeding (urea in most cases). Cattle fed urea treated silages (table 9) showed no clear advantages in gains or feed efficiencies over those fed urea supplemented control silage. Cash et al. (1971) did find that calves fed 2.1% urea-mineral mixture added to corn silage (35% DM) significantly out

performed those fed the control silage supplemented with Pro-Sil (ammonia-mineral suspension formulated to 85% CP). In two trials, cattle fed Pro-Sil treated silages (table 10) gained faster (P<.05) and were more efficient (P<.05) than those fed the control silage supplemented with Pro-Sil or urea (Cash et al., 1971 and Kuhl et al., 1980). Miller et al. (1979)

TABLE 9. Comparison of urea treated corn silage with control silage supplemented with NPN at the time of feeding.

Author	Year	Urea levels, %	Test cattle	---ADG, kg--- NPN	control	-----F/G----- NPN	control
Owens et al.	1967	.5	calves	.85	.91	13.32	13.38
Meiske et al.	1968	.5	calves	.78	.77	11.72	11.59
Cash et al.	1971[1]	2.1	calves	.88[b]	.74[a]	8.92	10.25
Miller et al.	1979	1.0	steers	1.09	1.08	6.63	6.71

[1] Pro-Sil, ammonia-mineral suspension, used as NPN supplementation.
[a,b] P<.05.

TABLE 10. Comparison of ammonia treated corn silage with the control silage supplemented with NPN at the time of feeding.

Author	Year	NH_3 levels and form, %	Test cattle	---ADG, kg--- NH_3	control	-----F/G----- NH_3	control
Cash et al.	1971[1]	2.5 Pro-Sil	calves	.87[b]	.74[a]	8.74	10.25
Miller et al.	1979	NH_3	steers	1.09	1.08	7.18	6.71
Bolsen et al.	1980b	.4 Cold-flo	heifers	.93	.91	7.93	8.21
Kuhl et al.	1980	2.5 Pro-Sil	heifers	.91[b]	.82[a]	8.58[a]	9.58[b]
Buchanan-Smith	1982	1.0 Cold-flo	steers[2]	1.31	1.22	6.66	7.01
			steers[3]	1.30	1.24	7.21	7.00

[1] Pro-Sil, ammonia-mineral suspension, used as NPN supplementation.
[2] 28% DM silages.
[3] 40% DM silages.
[a,b] P<.05.

evaluated ammonia addition to corn silage (34-39% DM) and found no difference in daily gains and a reduction in feed efficiency for calves fed treated silage verses those fed urea supplemented control silage. Bolsen et al. (1980b) applied ammonia as Cold-flo at .4% ammonia on fresh weight basis to corn silage (41-46% DM). They found no difference in daily gains but an improvement in feed conversion in favor of the Cold-flo treated silage compared with urea supplemented control silage.

Cattle fed urea treated silages generally gained slower and were less efficient than those fed control silage supplemented with natural protein (table 11). Urea levels from .5 to 2.5% of the fresh crop have been studied. Brethour (1976, 1977a) applied 2.5% of a molasses-urea mixture (50% CP) to forage sorghum. He found that the treated silage depressed gains in both trials (significantly in trial 1) and did not affect feed efficiency in trial 1 but greatly reduced feed efficiency in trial 2.

Cash et al. (1971) used a 2.1% urea-mineral mixture on 41-46% DM corn and found that 229 kg calves fed the treated silage out performed the control calves fed soybean meal. Calves on the urea-treated silage out gained ($P<.05$) the calves on the control silage supplemented with natural protein (SBM) while also improving feed efficiency.

Pro-Sil additions prior to ensiling generally gave similar or lower daily gains than the control silage supplemented with natural protein (table 12). An exception was Cash et al. (1971) who found an increase ($P<.05$) in gain and feed effiency for Pro-Sil over the control. Some researchers have found improved efficiencies with the addition of Pro-Sil (Beattie et al., 1971; Henderson et al., 1971b,e; Fox and Cook, 1976) while others have found depressed feed conversions (Henderson et al., 1971a,d).

Henderson et al. (1971d) applied at 2.25% aqueous ammonia to whole-plant corn (28-32% DM). They noted depressed gain and feed efficency for the

TABLE 11. Comparison of urea treated corn silage with control silage supplemented with natural protein at the time of feeding.

Author	Year	Urea levels, %	Test cattle	ADG, kg NPN	ADG, kg control	F/G NPN	F/G control
Harvey et al.	1964	1.0	calves	.72	.73	8.74	8.65
Jordan et al.	1965	1.0	calves	.64	.66	10.02	9.61
Owens et al.	1967	.5	calves	.85	.98	13.32	12.81
Beattie et al.	1971	.6	steers	1.04	1.05	7.94	8.22
Cash et al.	1971	.6	calves	.88[b]	.80[a]	8.92	9.88
Henderson et al.	1971d[2]	2.25	steers	1.00	1.15	7.74	7.79
Brethour	1976[1]	.5	calves	.68	.88	11.66	8.84
		2.5[3]		.71	.88	11.48	8.84
Brethour	1977a[1]	2.5[3]	steers	.89[a]	.99[b]	7.89	7.55

[1] Forage sorghum silage.
[2] Urea-mineral mixture.
[3] Molasses-urea mixture.
[a,b] $P<.05$.

treated silage over the SBM supplemented control silage. Fox and Cook (1976) reported similar results while those of Henderson et al. (1971b) showed no depression in gain and a slight improvement in feed efficiency with Pro-Sil.

Applying ammonia as Cold-flo has generally shown depressed cattle gains (Fox and Cook, 1976; Bolsen et al., 1980b; Bolsen and Ilg, 1981b) and feed efficiencies (Cook and Fox, 1976; Fox and Cook, 1976; Bolsen et al., 1980b) when compared with control silage supplemented with natural protein. However, Cook and Fox (1976) reported that .3% ammonia did not lower gain and Bolsen and Ilg (1981b) noted that with .6% ammonia feed efficiency was slightly improved.

Some of the reasons for such variability in cattle performance are due to the variable results that the NPN addition has on the forage. Silages treated with NPN usually have higher pH values than control silages due to

TABLE 12. Comparison of ammonia treated corn silage with the control silage supplemented with natural protein at the time of feeding.

Author	Year	NH_3 levels and form, %	Test cattle	ADG, kg		F/G	
				NH_3	control	NH_3	control
Beattie et al.	1971	2.25 Pro-Sil	steers	1.04	1.05	7.60	8.22
Cash et al.	1971	2.25 Pro-Sil	steers	.87[b]	.80[a]	7.57	7.88
Henderson et al.	1971a	2.25 Pro-Sil	steers	.84	.84	9.93	9.79
Henderson et al.	1971b	2.25 Pro-Sil	calves	1.21	1.22	5.42	5.79
		2.25 Aqua NH_4		1.20	1.22	5.49	5.79
Henderson et al.	1971c	1.5 Pro-Sil	steers	.94	1.05	8.61	8.22
		2.25 Pro-Sil		1.05	1.05	7.60	8.22
		3.0 Pro-Sil		.78[a]	1.05[b]	9.11	8.22
Henderson et al.	1971d	2.25 Pro-Sil	steers	.96	1.15	8.50	7.79
		2.25 Aqua NH_4		.97	1.15	7.92	7.79
Henderson et al.	1971e	3.0 Pro-Sil	steers	1.25	1.24	7.27	8.12
Brethour	1974[2]	2.0 Pro-Sil	calves	.55	.71	ND	ND
Cook and Fox	1976	.3 Cold-flo	steers	1.11	1.11	6.64	6.35
Fox and Cook	1976	Pro-Sil	calves	1.15	1.14	6.72	6.92
		Aqua NH_4		1.09	1.14	7.19	6.92
		Cold-flo		1.06	1.14	7.45	6.92
Bolsen et al.	1980b[2]	.4 Cold-flo	heifers	.93	.98	7.93	7.28
Bolsen and Ilg	1981b	.6 Cold-flo	heifers	.49	.53	10.34	10.66

[1]ND means not determined.
[2] Forage sorghum silage.
[a,b] $P<.05$.

the additional buffering of fermentation acids by free ammonia (Cash et al., 1971; Huber et al., 1973; Singh and Pandit, 1978). Since fermentation is prolonged, lactic acid levels are increased in NPN silages. A few workers have noted an increased clostridial activity when Pro-Sil and Cold-flo were used as the NPN addition (Henderson et al., 1971a; Bolsen and Ilg, 1981a,b). NPN treated silages usually contain increased concentrations of non-protein nitrogen and ammonia (Beattie et al., 1971; Cash et al., 1971; Henderson et al., 1971d; Huber et al., 1973), but the degradation of "true" protein was

reduced (Cash et al., 1971 and Buchanan-Smith, 1982). Silage aerobic stability tends to be improved by NPN additions (Soper and Owen, 1977; Huber et al., 1979; Ahrens et al., 1981; Bolsen and Ilg, 1981a,b), however, Bolsen et al. (1980b) noted that Cold-flo reduced aerobic stability in one trial. Digestibilities of corn silage dry matter and crude protein were lower ($P<.01$) when Pro-Sil corn silage (40% DM) was compared to SBM supplemented control silage (Luther et al., 1982). Bolsen et al. (1981c) also found lower ($P<.05$) crude protein digestibility but similar dry matter digestibility of Cold-flo treated sorghum silage (32-35% DM) and control silage supplemented with soybean meal.

For the NPN addition to be of value it must be evenly dispersed and remain in the forage mass. Recovery of crude protein equivalents of NPN applied to the crop at the time of ensiling have varied from 48-99 percent. If rations were formulated on a theoretical CP based on the amount of NPN applied, this could leave them deficient in protein, particularly if large amounts of NPN were not recovered in the silage. These protein recovery differences could explain most of the differences in cattle performance observed in several of the NPN treated silage trials.

LITERATURE CITED

Ahrens, K. R., J. W. Thomas, T. R. Johnson, and B. W. Jesse. 1981. Haylage with inoculant or ammonia as additives. J. Anim. Sci. 51:Suppl 1:270 (Abstr.).

Anonomous. 1980. Silage Management. Pioneer Hi-Bred International. Des Moines, Iowa.

Baker, R. J. and H. H. Voelker. 1958. Preservatives for alfalfa silages. J. Dairy Sci. 41:734 (Abstr.).

Beattie, D. R., H. E. Henderson, M. R. Geasler, and W. G. Bergen. 1971. Pro-Sil and urea addition to corn silage. Report of Beef Cattle Research AH-BC-694. p. 23. Michigan State University. East Lansing, Michigan.

Beck, T. 1965. Untersuchungen uber die okologie und physiologie der Garfutterflora. Landw. Forsch. 18:243.

Beck, T. 1978. The micro-biology of silage fermentation. In Fermentation of Silage--a Review. (Ed. McCullough, M. E.) Ch. 3. p. 63-115. Des Moines, Iowa: National Feed Ingredient Association.

Beck, T. and F. Gross. 1964. Das Wirtschaftseigene Futter. 10:45.

Black, J. R., L. O. Ely, M. E. McCullough, and E. M. Sudweeks. 1980. Effects of stage of maturity and silage additives upon the yield of gross and digestible energy in sorghum silage. J. Anim. Sci. 50:617.

Bolsen, K., H. Ilg, and D. Axe. 1981c. Sila-bac, Cold-flo, sodium hydroxide, and Harvestore forage sorghum silages for lambs. Agric. Exp. Sta. Report of Progress 396. p. 34. Kansas State University. Manhattan, Kansas.

Bolsen, K., H. Ilg, and J. Riley. 1980b. Cold-flo, Sila-bac, and Silo-Best for corn silage. Agric. Exp. Sta. Report of Progress 377. p. 55. Kansas State University. Manhattan, Kansas.

Bolsen, K. K. and H. J. Ilg. 1981a. Inoculant, enzyme, NPN, or NaOH additives for corn and sorghum silages: fermentation and aerobic stability. J. Anim. Sci. 53:Suppl 1:382 (Abstr.).

Bolsen, K. K. and H. J. Ilg. 1981b. Inoculant, enzyme, NPN, or NaOH additives for corn and sorghum silages: cattle performance. J. Anim. Sci. 53:Suppl 1:382 (Abstr.).

Bolsen, K. K., H. J. Ilg, and D. E. Axe. 1980a. Additives for alfalfa silage. J. Anim. Sci. 51:Suppl 1:230 (Abstr.).

Bolsen, K. K., H. J. Ilg, and M. A. Hinds. 1981b. Inoculant and enzyme additives for alfalfa silage and corn supplementation for steers. J. Anim. Sci. 53:Suppl 1:383 (Abstr.).

Bolsen, K. K., M. A. Hinds, and H. J. Ilg. 1981a. Effect of inoculant and enzyme additives and silo type on alfalfa silage fermentation, aerobic stability, and digestibility. J. Anim. Sci. 53:Suppl 1:382 (Abstr.).

Breirem, K. and O. Ulvesli. 1960. Ensiling methods. Herbage Abstr. 30:1.

Brethour, J. 1967. Additions to forage sorghum silage fed to wintering steer calves. Agric. Exp. Sta. Report of Progress 506. p. 8. Kansas State University. Manhattan, Kansas.

Brethour, J. 1974. Using "Pro-Sil" and "Direct cut" silage preservatives with sorghum silage. Agric. Exp. Sta. Report of Progress 215. p. 8. Kansas State University. Manhattan, Kansas.

Brethour, J. 1976. Treating sorghum silage with dry urea or a liquid-urea supplement. Agric. Exp. Sta. Report of Progress 266. p. 21. Kansas State University. Manhattan, Kansas.

Brethour, J. 1977a. Ensiling urea-molasses supplement with silage. Agric. Exp. Sta. Report of Progress 297. p. 3. Kansas State University. Manhattan, Kansas.

Brethour, J. 1977b. Alfalfa silage with and without a commercial preservative. Agric. Exp. Sta. Report of Progress 297. p. 3. Kansas State University. Manhattan, Kansas.

Brethour, J. 1978a. Alfalfa silage with and without a commercial preservative. Agric. Exp. Sta. Report of Progress 326. p. 3. Kansas State University. Manhattan, Kansas.

Brethour, J. 1978b. Pioneer 931 forage sorghum silage and Sila-bac preservative. Agric. Exp. Sta. Report of Progress 326. p. 3. Kansas State University. Manhattan, Kansas.

Brethour, J. 1979. Preservatives in forage sorghum silage. Agric. Exp. Sta. Report of Progress 356. p. 3. Kansas State University. Manhattan, Kansas.

Brethour, J. 1980. Inoculants in forage sorghum silage. Agric. Exp. Sta. Report of Progress 384. p. 3. Kansas State University. Manhattan, Kansas.

Brown, W. O. and J. A. Kerr. 1965. Losses in the conservation of heavily-wilted herbage sealed in polythene film in lined trench silos. J. Br. Grassl. Cong. 20:227.

Buchanan-Smith, J. G. 1982. Preservation and feeding value for yearling steers of whole-plant corn ensiled at 28 and 48% dry matter with and without cold flow ammonia treatment. Can. J. Anim. Sci. 62:173.

Buchanan-Smith, J. G. and Y. T. Yao. 1981. Effect of additives containing lactic acid bacteria and/or hydrolytic enzymes with antioxidant upon the preservation of corn or alfalfa silage. Can. J. Anim. Sci. 61:669.

Burghardi, S. R., R. D. Goodrich, and J. C. Meiske. 1980. Evaluation of corn silage treated with microbial additives. J. Anim. Sci. 50:729.

Carpintero, C. M., A. R. Henderson, and P. McDonald. 1979. The effect of some pre-treatments on proteolysis during the ensiling of herbage. Grass and Forage Sci. 34:311.

Cash, E., H. E. Henderson, and W. G. Bergen. 1971. Corn silage additives and concentrate levels compared. Report of Beef Cattle Research AH-BC-704. p. 28. Michigan State University. East Lansing, Michigan.

Cook, R. J. and D. G. Fox. 1976. Anhydrous ammonia treated corn silage for feedlot cattle. Report of Beef Cattle Research AH-BC-7610. p. 96. Michigan State University. East Lansing, Michigan.

Daniel, P., H. Honig, F. Weise, and E. Zimmer. 1970. Das Wirtschaftseigene Futter 16:239.

El Hag, M., R. L. Vetter, and M. D. Kenealy. 1979. Silage additives, moisture, and energy effects on the fermentation of alfalfa in model laboratory silos. J. Anim. Sci. 49:Suppl 1:365.

Ely, L. O., N. J. Moon, E. M. Sudweeks, and M. E. McCullough. 1979. Evaluation of Lactobacillus additive on silage. J. Anim. Sci. 49:Suppl 1:366 (Abstr.).

Ely, L. O., E. M. Sudweeks, and N. J. Moon. 1981. Inoculation with Lactobacillus plantarum of alfalfa, corn, sorghum, and wheat silages. J. Dairy Sci. 64:2378.

Ely, L. O., N. J. Moon, and E. M. Sudweeks. 1980. Evaluation of Lactobacillus plantarum additives to alfalfa, corn, sorghum, and wheat silages. J. Dairy Sci. 63:150 (Abstr.).

Fox, D. G. and R. J. Cook. 1976. Performance of steer calves fed corn silage treated with three sources of anhydrous ammonia. Report of Beef Cattle Research AH-BC-7609. p. 89. Michigan State University. East Lansing, Michigan.

Goering, H. K. and D. R. Waldo. 1979. Corn silage and orchardgrass silage treated with inoculant for growing dairy heifers. J. Dairy Sci. 62:180 (Abstr.).

Gross, F. 1969. Steuerung des Garverlaufes durch Zusatzmittel. Proc 3rd Gen. Meeting Europ. Grassl. Fed. Bruanschweig. p. 140.

Gross, F. and K. Riebe. 1974. Garfutter. Verl. E. Ulmer Stuttgart.

Harvey, A. L., O. E. Kolari, and J. C. Meiske. 1964. Urea vs. soybean meal in all-in-one corn silage rations for wintering calves. Minnesota Agric. Exp. Sta. Beef Cattle Grassl. Field Day B-53. p. 7. University of Minnesota. St. Paul, Minnesota.

Heath, M. E., D. S. Metcalfe, and R. F. Barnes. 1976. Forages (3rd ed.). Iowa State University Press. Ames, Iowa.

Henderson, A. R., P. McDonald, and M. K. Woolford. 1972. Chemical changes and losses during the ensilage of wilted grass treated with formic acid. J. Sci. Food Agric. 23:1079.

Henderson, H. E., C. K. Allen, E. Cash, and W. G. Bergen. 1971a. Pro-Sil vs. soybean meal for supplementing 0%, 1/2%, 1%, 1 1/2%, and 2% concentrate rations. Report of Beef Cattle Research AH-BC-702. p. 5. Michigan State University. East Lansing, Michigan.

Henderson, H. E., D. R. Beattie, M. R. Geasler, and W. G. Bergen. 1971b. Molasses, minerals, ammonia, and Pro-Sil addition to corn silage for feedlot cattle. Report of Beef Cattle Research AH-BC-6950. p. 1. Michigan State University. East Lansing, Michigan.

Henderson, H. E., D. R. Beattie, M. R. Geasler, and W. G. Bergen. 1971c. Effect of level of Pro-Sil addition to corn silage on performance of yearling steers. Report of Beef Cattle Research AH-BC-6940. p. 15. Michigan State University. East Lansing, Michigan.

Henderson, H. E., D. R. Beattie, M. R. Geasler, and W. G. Bergen. 1971d. Pro-Sil, ammonia, urea-mineral, and urea addition to corn silage for feedlot cattle. Report of Beef Cattle Research AH-BC-6951. p. 33. Michigan State University. East Lansing, Michigan.

Henderson, H. E., D. R. Beattie, M. R. Geasler, and W. G. Bergen. 1971e. Pro-Sil treated vs. control corn silage with varying levels of concentrate addition for finishing yearling steers. Report of Beef Cattle Research AH-BC-6952. p. 41. Michigan State University. East Lansing, Michigan.

Hinds, M. A., K. K. Bolsen, and H. J. Ilg. 1982b. Alfalfa silages and hay and corn supplementation for steers. Amer. and Can. Soc. Anim. Sci. 1982 Meeting. p. 430 (Abstr.).

Hingston, A. R. and D. A. Christenson. 1982. The effect of type of silo and formic acid preservation on the nutritive value of barley, wheat and oat silages for growing Hereford steers. Can. J. Anim. Sci. 62:155.

Honig, H. and M. K. Woolford. 1979. Changes in silage on exposure to air. Br. Grassl. Soc. Occ. Symp. No. 11. p. 67.

Huber, J. T., L. Kung, Jr., A. Shanan, and D. S. Brecht. 1981. Effects of a microbial inocula or enzyme preparation on fermentation and proteolysis on alfalfa haylage. J. Dairy Sci. 64:112 (Abstr.).

Huber, J. T., R. E. Lichtenwalner, and J. W. Thomas. 1973. Factors affecting response of lactating cows to ammonia-treated corn silages. J. Dairy Sci. 56:1283.

Huber, J. T., R. E. Lichtenwalner, R. E. Ledebuhr, and C. M. Hansen. 1979. Gaseous ammonia treatment of corn silage for dairy cows. J. Dairy Sci. 62:965.

Jordan, R. M., J. C. Meiske, R. D. Goodrich, O. E. Kolari, and A. L. Harvey. 1965. All-in-one silage for wintering calves. Minnesota Agric. Exp. Sta. Beef Cattle Grassl. Field Day B-61. p. 17. University of Minnesota. St. Paul, Minnesota.

Kanemasu, E. T. 1977. Evapotranspiration from corn, sorghum, soybean, and winter wheat. Agric. Exp. Sta. Keeping Up With Research 30. Kansas State University. Manhattan, Kansas.

Kearney, P. C. and W. K. Kennedy. 1962. Relationship between losses of fermentable sugars and changes in organic acids of silage. Agron. J. 54:114.

Kroulik, J. T., L. A. Burkey, and H. G. Wiseman. 1955a. The microbial populations of the green plant and of the cut forage prior to ensiling. J. Dairy Sci. 38:256.

Kroulik, J. T., L. A. Burkey, C. H. Gordon, H. G. Wiseman, and C. G. Melin. 1955b. Microbial additives in alfalfa and orchardgrass ensiled under certain conditions in experimental silos. J. Dairy Sci. 38:263.

Kuhl, G., C. W. Carlson, L. B. Embry, and F. Shubeck. 1980. Feedlot performance of yearling heifers fed Pro-Sil treated on urea supplemented corn silage. 1980 Cattle Feeders Day 80-14. South Dakota State University. Brookings, South Dakota.

Lancaster, R. J. and M. McNaughton. 1961. Effects of initial consolidation on silage. N. Z. J. Agric. Res. 4:504.

Lesins, K. and F. H. Schultz. 1968. Some effects of bacterial inoculation on silage making. Can. J. Anim. Sci. 48:15.

Luther, R. M. and J. Nothnagel. 1982. Untreated and microbial inoculated corn silage in high silage rations for beef steers. 1982 Cattle Feeders Day. p. 1. South Dakota State Unversity. Brookings, South Dakota.

McCullough, M. E. 1977. Silage and silage fermentation. Feedstuffs March 28, 1977. p. 49.

McCullough, M. E. 1978. Silage--Some general considerations. In Fermentation of Silage--A Review. (Ed. McCullough, M. E.) Ch. 1. p. 1-26. Des Moines, Iowa: National Feed Ingredient Association.

McDonald, P. 1981. The Biochemistry of Silage. John Wiley and Sons. New York.

McDonald, P., A. C. Stirling, A. R. Henderson, and R. Whittenbury. 1964. Fermentation studies on inoculated herbages. J. Sci. Food Agric. 15:429.

McDonald, P., A. C. Stirling, A. R. Henderson, and R. Whittenbury. 1965. Fermentation studies on red clover. J. Sci. Food Agric. 16:549.

McDonald, P. and R. A. Edwards. 1976. The influence of conservation methods on digestion and utilization of forages by ruminants. Proc. Nutr. Soc. 35:201.

Meiske, J. C., R. D. Goodrich, and F. N. Owens. 1968. Supplementation of corn silage rations for growing calves with urea and biuret at ensiling or feeding time. 1968 Minnesota Cattle Feeders' Report. p. 45. University of Minnesota. St. Paul, Minnesota.

Miller, B. L., R. D. Goodrich, and J. C. Meiske. 1979. NPN-treated corn silage in steer finishing rations. 1979 Minnesota Cattle Feeders' Report. University of Minnesota. St. Paul, Minnesota.

Miller, W. J., H. L. Dalton, and J. K. Miller. 1961. Sudan grass at two stages of maturity versus rye grass and crimson clover with two filling procedures. J. Dairy Sci. 44:1921.

Mo, M. and E. Fyrileiv. 1979. Methods of estimating ensiling losses. Acta Agr. Scand. 29:49.

Moon, N. J. and L. O. Ely. 1981. Addition of Lactobacillus species to aid the fermentation of alfalfa, corn, sorghum, and wheat forages. 14th Int. Grassl. Cong. p. 348.

Moon, N. J., L. O. Ely, and E. M. Sudweeks. 1980. Effect of Lactobacillus plantarum additive on alfalfa, corn, sorghum, and wheat silages. J. Dairy Sci. 63:150 (Abstr.).

Moon, N. J., L. O. Ely, and E. M. Sudweeks. 1981. Fermentation of wheat, corn, and alfalfa silages inoculated with Lactobacillus acidophilus and Candida spp. at ensiling. J. Dairy Sci. 64:807.

Moon, N. J., L. O. Ely, E. M. Sudweeks, and M. E. McCullough. 1979. Effect of inoculation of Lactobacillus acidophilus in wheat, alfalfa, and corn silage on microbial populations and pH during fermentation. J. Dairy Sci. 62:183 (Abstr.).

Nilsson, G. and P. E. Nilsson. 1956. The microflora on the surface of some fodder plants at different stages of maturity. Arch. Mikrobiol. 24:412.

Ohyama, Y., T. Morichi, and S. Masaki. 1975. The effect of inoculation with Lactobacillus plantarum and addition of glucose at ensiling on the quality of aerated silages. J. Sci. Food Agric. 26:1001.

O'Leary, J. and R. W. Hemken. 1980. Effect of frozen concentrated culture on fermentation of corn silage. J. Dairy Sci. 63:150 (Abstr.).

O'Leary, J., L. S. Bull, and D. W. Rice. 1979. An evaluation of silage additives. J. Dairy Sci. 62:184 (Abstr.).

O'Leary, J., R. W. Hemken, and K. A. Dawson. 1981. Inoculation of corn and alfalfa silages with a mixed frozen concentrated culture. J. Dairy Sci. 64:114 (Abstr.).

Owens, F. N., J. C. Meiske, and R. D. Goodrich. 1967. Supplementation of high corn silage rations for wintering calves, with urea, biuret, or soybean meal at ensiling or feeding time. 1967 Minnesota Beef Feeders' Report B-87. p. 21. University of Minnesota. St. Paul, Minnesota.

Rakshit, C. C. and H. H. Voelker. 1981. Effects of additives on preservation of alfalfa silage, corn silage, and corn stillage. J. Dairy Sci. 64:115 (Abstr.).

Ruxton, I. B., B. J. Clark, and P. McDonald. 1975. A review of the effects of oxygen on ensilage. J. Br. Grassl. Soc. 30:23.

Singh, A. P. and N. N. Pandit. 1978. Studies on fermentation of sorghum silage during storage--effect of urea and molasses. Anim. Feed Sci. Tech. 3:299.

Soper, I. G. and F. G. Owens. 1977. Improving silage preservation and stability with an ammonia-molasses-mineral solution. J. Dairy Sci. 60:1077.

Speckman, C. A., R. M. Phillips, D. P. Linnertz, J. C. A. Berger, L. A. Carver, and R. B. Parker. 1981. Lactobacillus populations of the epiphytic flora of corn just prior to ensiling. J. Anim. Sci. 51:270 (Abstr.).

Sprague, M. A. 1974. Oxygen disappearance in alfalfa silage. Proc. 12th Int. Grassl. Cong. p. 651.

Stirling, A. C. 1953. Lactobacilli and silage-making. Proc. Soc. Appl. Bact. 16:27.

Stirling, A. C. and R. Whittenbury. 1963. Sources of the lactic acid bacteria occurring in silage. J. Appl. Bact. 26:86.

Thonney, M. L., D. J. Duhaime, T. C. Jenkins, and C. A. Ruppel. 1980. Microbial and chemical additives on alfalfa-timothy silage. J. Dairy Sci. 63:587.

Vanderlip, R. L. 1979. How a sorghum plant develops. Agric. Exp. Sta. Circular S-3. Kansas State University. Manhattan, Kansas.

Waldo, D. R. 1979. Silage fermentation, preservatives and additives. J. Anim. Sci. 51:Suppl 1:57 (Abstr.).

Waldo, D. R. and H. K. Goering. 1976. Alfalfa, orchardgrass, and corn ensiled with additives. J. Anim. Sci. 42:1582 (Abstr.).

Whittenbury, R. 1961. An investigation of the lactic acid bacteria. PhD. Thesis. University of Edinburgh.

Wieringa, G. W. 1961. Uber den EinfluB des Grunfutters auf die Garung. Futterkons. 7:27.

Wilson, R. F. and R. J. Wilkins. 1972. An evaluation of laboratory ensiling techniques. J. Sci. Food Agric. 23:377.

Woods, W. and W. Tolman. 1968. Urea: Corn silage supplement. Nebraska Cattle Feeders 1968. p. 11. University of Nebraska. Lincoln, Nebraska.

Woods, W. and W. Tolman. 1969. Urea, soybean meal as supplements. Nebraska Cattle Feeders 1969. p. 10. University of Nebraska. Lincoln, Nebraska.

Woods, W., W. Tolman, D. Stenberg, and L. Harris. 1968. Urea additions to corn silage. Nebraska Cattle Feeders 1968. p. 5. University of Nebraska. Lincoln, Nebraska.

Yoder, J. M., D. L. Hill, and N. S. Lunquist. 1960. The effect of varying the period of time between chopping and sealing on the ensiling of unwilted forage in plastic laboratory silos. J. Anim. Sci. 19:Suppl 1:1315 (Abstr.).

Zimmer, E. 1977. Factors affecting fodder conservation. Proc. Int. Meeting on Anim. Prod. from Temperate Grassl. p. 121.

Zimmer, E. 1979. Efficient silage systems. Br. Grassl. Soc. Occ. Symp. No. 11. p.186.

EXPERIMENTAL PROCEDURES

Experiment 1: 1980-81 Hays Branch Agriculture Experiment Station

Farm-scale Silos: Forage sorghum silages were made in October of 1980, using Asgrow's Titan E hybrid direct-cut in the hard-dough stage at 29 to 32% dry matter (DM). Treatments were: 1) control (no additive); 2) LSA-100[1] (1.7% of the fresh crop); and 3) Sila-bac[2] (.05% of the fresh crop). Additives were applied by hand at the silo blower and silages were made in concrete stave silos (3 m X 9 m).

Dry matter losses during fermentation, storage, and feedout were measured by accurately weighing and sampling all loads of fresh crop ensiled and later weighing and sampling all silage removed from the silos. Ensiling temperatures were monitored for the first 7 weeks at three locations within each silo (after loads 1, 3, and 5) with equally spaced thermocouple wires soldered to 30 cm pieces of copper tubing. An Omega digital thermometer was used to measure the temperatures.

Stave silos were opened after 50 d and the silage was fed at a uniform rate for the following 10 weeks. Silages were sampled weekly and composited to form a biweekly sample for chemical analyses. The wet samples were stored at -10 C until analyzed.

Forage DM was determined by drying for 48 h at 55 C in a forced-draft oven with no corrections for volatile losses. The dried sample was subsequently ground with a Wiley mill to pass through a 1 mm screen.

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[1] LSA-100 ^{R} liquid feed (molasses, urea, phosphoric and sulfuric acids to reduce pH to 3.0-3.2, ammonium polyphosphate, and trace minerals) contains 100% crude protein (not more than 99.5% non-protein nitrogen), Namalco, Inc., Willow Grove, PA, 19090.

[2] Sila-bac^{R} Silage Inoculant contains dried Lactobacillus plantarum culture and dried Lactobacillus acidophilus culture (guaranteed total lactobacillus count of $4x10^{6}$ colony forming units per g), Pioneer Hi-Bred International, Inc., Des Moines, IA, 50308.

Proximate analyses were determined by AOAC (1970) methods and hot water insoluble-nitrogen by Goering and Van Soest (1970).

The portion of the sample not dried had a 25 g aliquot extracted in 100 ml of distilled water for 1 h to determine pH. Another 25 g aliquot was extracted in 200 ml of .2 N H_2SO_4 for 2 d and the supernate was strained through 4 layers of cheesecloth from the mixture and retained for futher analyses. From the supernate lactic acid was determined by colorimetric determination (Barker and Summerson, 1941); ammonia-nitrogen by the Conway microdiffusion method (Conway, 1957); and volatile fatty acids (VFA) by gas chromatography. VFA were seperated on a 183.0 cm by 4.0 mm glass column packed with (80-100 mesh) Chromosorb 101 using a flash vaporization inlet, hydrogen flame detection, and an oven temperature of 200 C (isothermal). The carrier gas was nitrogen.

Laboratory Silos: During the filling of the farm-scale silos, 204 kg of fresh crop was removed from each silo. For each treatment, 12 plastic container silos (20 l capacity) and six nylon bags (20 l capacity) were tightly filled by hand with forage sorghum. The containers were made air excluding by a lid fitted a rubber O-ring seal and Bunsen valve, then transported immediately to Manhattan and stored at 20 to 25 C. Three nylon bags were buried at two depths in their respective stave silo.

The plastic silos were opened in duplicate for each silage treatment on d 1, 2, 3, 4, 12, and 122 post-ensiling. The nylon bags (three/silo) were recovered at approximately 25 and 60 d after the stave silos were opened. The entire content of each laboratory silo was weighed, mixed, and sampled and the samples analyzed similarly to the farm-scale silage samples described in Experiment 1.

Aerobic Stability Measurements: Approximately 25 kg of fresh silage was obtained from the middle of each farm-scale silo at 1 m below the exposed

surface during the feeding of the silages. The silage was transported immediately to Manhattan for processing.

The silages were divided into 12 equal lots of 2 kg and each lot was placed in an expanded polystyrene container lined with plastic. A thermocouple, consisting of the wire lead inserted into a Vacuutainer brand collection tube filled with mineral oil, was inserted into the geometric center of the silage and cheesecloth was placed over each container to prevent dust contamination. Containers were stored at 18.3 C and temperatures were recorded twice daily. Three containers of each silage were weighed, mixed, and sampled after 3, 5, 9, and 13 d of air exposure. Samples were analyzed for dry matter as previously described.

Steer Growth Trial: Forty-five crossbred steers were fed in an 81 d growth trial (December 22, 1980 to March 12, 1981). The steers, averaging 231 kg, were randomly allotted by weight, breed, and previous gains to the three silage diets (one pen of 15 steers/diet). Diets were the appropriate silage fed ad libitum once daily plus .68 kg of supplemental ingredients that included .51 kg of soybean meal (SBM), .10 kg of premix, .04 kg of $(NH_4)_2SO_4$, and .04 kg of ground limestone on a dry matter basis (table 21). In the LSA-100 silage diet .30 kg of rolled grain sorghum replaced an equal amount of soybean meal. Diets were formulated to 11.9% crude protein (CP) and were equal in minerals, vitamins, and additives. The 11.9% was the calculated theoretical CP value for the LSA-100 silage diet. Steers were implanted with 36 mg of Ralgro at the start of the trial.

Average initial and final steer weights were on a pay-weight to pay-weight basis. To allow for weight loss during the weighing day, the steers were weighed collectively by pens, at the start of each weighing day and then weighed individually. All individual steer weights were pencil shrunk 4.0% to obtain the adjusted individual steer weights.

Lamb Digestion Trial: Twenty-five crossbred wether lambs (averaging 36 kg) were allotted by weight to five silage diets (five lambs/diet). All diets were 85% silage and 15% supplement on a dry matter basis (table 13). Diets were formulated to contain 11.9% CP and supplied equal amounts of minerals and vitamins. The control silage was fed with SBM, urea, or LSA-100 as supplemental nitrogen sources; Sila-bac silage, with SBM; and LSA-100, without supplemental nitrogen.

TABLE 13. Composition of average lamb diet fed during voluntary intake period.

Item	Control silage +SBM	Control silage +urea	Control silage +LSA-100	LSA-100 silage	Sila-bac silage
Ave. daily feed intake, g[1]					
sorghum silage	973.8	921.2	982.1	1065.1	1141.2
soybean meal	154.2	---	13.9	14.7	180.6
grain sorghum	---	122.8	145.1	152.9	---
urea	---	20.4	---	---	---
LSA-100	---	---	28.8	---	---
limestone	8.5	6.9	10.3	10.8	10.0
dicalcium phosphate	2.3	5.9	2.0	2.1	2.7
premix[2]	6.9	6.5	7.1	7.5	8.1
total	1145.7	1083.7	1189.3	1253.1	1342.6

[1]100% dry matter basis.
[2]Premix contained 60.88% salt, 24.3% tallow, 12.1% trace minerals, 2.8% vitamin mix which provided 3000 IU of vitamin A, 300 IU vitamin D, and 3 vitamin E per lamb daily.

The 37 d trial was divided into 20 d ad libitum pre-feeding, 7 d voluntary intake, 3 d diet adjustment, and 7 d fecal and urine collection periods. During the adjustment and collection periods, all lambs received 80% of their previously established ad libitum intake.

Silage was obtained every 5 to 7 d from each of the three farm-scale silos described in Experiment 1. The silage was tightly packed into plastic-lined 208 l drums, transported to Manhattan, and stored at ambient temperature until fed.

Lambs were fitted with a canvas harness equipped with a fecal collection bag and fed individually in metal digestion crates. Daily fecal collections

were weighed and a 10% aliquot was retained and its DM determined daily. Crates were equipped with stainless steel trays below the wire-mesh floor to direct the urine into a plastic bucket containing 50 ml of 18 N HCl to maintain acidity. Urine collections were diluted with water to the next highest liter and a 10% aliquot was taken and stored in glass bottles. Diet samples were taken daily during the 7 d voluntary intake and 7 d collection periods with DM determined daily. At the end of the trial the diet, feces, and urine samples for each lamb were composited, mixed, subsampled, and processed for laboratory analyses. A 500 g wet diet sample was frozen for later analyses.

Diets and feces were dried at 55 C for 48 h and ground with a Wiley mill to pass through a 1 mm screen. Diets, feces, and urine samples were analyzed for nitrogen by the Kjeldahl method as outlined by AOAC (1965). Proximate analyses were determined for diets and feces by AOAC (1970) methods.

Experiment 2: 1981-82 Hays Branch Agriculture Experiment Station

Farm-scale Silos: Forage sorghum silages were made in September of 1981, using DeKalb FS4 hybrid direct-cut in the medium-dough stage at 27 to 29 % dry matter. Treatments were: 1) control (no additive) and 2) LSA-100 (1.8% of the fresh crop). Additives were applied by hand at the blower and silages were made in two concrete stave silos (3 m X 9 m).

Dry matter losses during fermentation, storage, and feedout and ensiling temperatures during the first 10 weeks were measured as previously described in Experiment 1.

Stave silos were opened after 70 d and each silage was fed at a uniform rate to 15 steers for the following 17 weeks. Silage sampling procedures and analyses were the same as previously described.

Laboratory Silos: During the filling of the farm-scale silos, 100 kg of fresh crop was removed from each silo. For each treatment, six plastic container silos (described previously in Experiment 1) were tightly filled

with forage sorghum and immediately transported to Manhattan for storage at 25 to 30 C.

The plastic silos were all opened at the end of the steer growing trial, approximately 210 d post-ensiling. Each plastic silo was sampled and analyzed as described in Experiment 1.

Aerobic Stability Measurements: Samples for aerobic stability measurements were taken from the farm-scale silos and prepared as described in Experiment 1. Three separate stability measurements were made with silages removed from the top, middle, and bottom thirds of the silos.

The first measurement had 12 equal lots per silage with triplicate containers of each silage weighed, mixed, and sampled after 2 and 4 d of air exposure. Temperatures were recorded for 7 days. The second measurement had nine lots with triplicate containers removed after 3, 9, and 22 d of air exposure. The third measurement had six lots with duplicate containers removed after 5, 8, and 13 days. All samples were analyzed for DM as previously described in Experiment 1.

Steer Growth Trial: Thirty crossbred steers were fed in a 122 d growth trial (November 20, 1981 to March 21, 1982). The steers, averaging 227 kg, were allotted as described in Experiment 1. Diets were the appropriate silage fed ad libitum once daily plus 1.01 kg of supplemental ingredients that included .83 kg of SBM and .18 kg of premix on a dry matter basis (table 29). In the LSA-100 silage diet, .63 kg of rolled grain sorghum replaced an equal amount of soybean meal. Diets were formulated to 12.0% CP and were equal in minerals, vitamins, and additives. Steers were implanted with 36 mg of Ralgro at the start of the trial and initial and final weights were obtained as described in Experiment 1.

Experiment 3: 1981-82 Kansas State University, Manhattan

Farm-scale Silos: Forage sorghum silages were made in October of 1981, using Pioneer 947 hybrid direct-cut in the hard-dough stage at 42 to 43 % dry

matter. Treatments were: 1) control (no additive); 2) LSA-100 (2.0% of the fresh crop); and 3) 1177[1] (.05% of the fresh crop). LSA-100 was poured over the top of each load of crop just prior to ensiling and 1177 was applied by hand at the blower. Silages were made in three concrete stave silos (3 m X 15 m) and the silos were filled by the alternate-load method. Total harvest and filling time was 6 hours.

Dry matter losses during fermentation, storage, and feedout and ensiling temperatures during the first 5 weeks were measured as previously described in Experiment 1.

Stave silos were opened after 21 d and each silage was fed at an uniform rate for the following 8 weeks. Silage sampling procedures and analyses were the same as previously described (Experiment 1).

Laboratory Silos: During the filling of each farm-scale silo, 230 kg of fresh crop and the appropriate additive were mixed in a Davis double-ribbon mixer for 10 minutes. For each treatment, 14 plastic container silos and six nylon bags (described in Experiment 1) were tightly filled with forage sorghum by a hydraulic press. Plastic silos were stored at 25 to 30 C; three nylon bags were buried at two depths in their respective stave silo.

The plastic silos were opened in duplicate for each silage treatment on d 1, 2, 4, 12 and in sextuplet on d 70 post-ensiling. The nylon bags (three/silo) were recovered approximately 10 and 45 d after the stave silos were opened. Each plastic silo and nylon bag was sampled and analyzed as described in Experiment 1.

Aerobic Stability Measurements: Samples for aerobic stability measurements were taken from the farm-scale silos and prepared as described

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[1]Pioneer 1177[R] Silage Inoculant contains dried Lactobacillus plantarum fermentation product and dried Streptococcus faecium fermentation product, Pioneer Hi-Bred International, Inc., Des Moines, IA, 50308.

in Experiment 1. Two separate stability measurement were made with silages removed from the top and bottom halves of the silos.

Each measurement had 12 equal lots per silage with triplicate containers of each silage weighed, mixed, and sampled after 2 and 4 d of air exposure. Temperatures were recorded for the remaining containers for 8 d in each measurement. All samples were analyzed for DM as described in Experiment 1.

Steer Growth Trial: Thirty-six crossbred steers were individually fed in a 56 d growth trial (November 9, 1981 to January 4, 1982). The steers, averaging 221 kg, were allotted by weight to the three silage diets (12 steers/diet). Diets were the appropriate silage fed ad libitum twice daily plus 1.01 kg of supplemental ingredients that included .91 kg of SBM, .04 kg of rolled grain sorghum, .03 kg of limestone, and .03 kg of premix on a dry matter basis (table 38). In the LSA-100 silage diet, .71 kg of rolled grain sorghum replaced an equal amount of soybean meal. Diets were formulated to 12.5% CP and were equal minerals, vitamins, and additives. Steers were implanted with 36 mg of Ralgro at the start of the trial. All steers were weighed individually on 2 consecutive days, after 16 h without feed and water, at the start and the end of the growing trial.

Statistical Analyses

Temperatures from the silos and aerobic stability trials were not statistically analyzed because the samples were repeated measures from individual silos.

The end-product silages from the 20 l plastic containers and lamb digestion and nitrogen balance data were analyzed by analysis of variance of a one-way treatment structure (Snedecor and Cochran, 1981). The dynamics of the silage fermentation characteristics were analyzed by a nonlinear model comparison technique (Milliken and DeBruin, 1978; SAS PROC NLIN, SAS USER's GUIDE, SAS Institute, 1979; Appendix A). The silage characteristics for all three trials from the concrete stave silos, nylon bags, and 20 l containers

were pooled to be analyzed as a multivariate analysis of variance (SAS PROC GLM/MANOVA option, SAS USER's GUIDE,SAS Institutes, 1979; Chatfield and Collins, 1980) and an incomplete block analysis of variance of a two-way treatment structure with silo type and silage treatment as the main effects and trial as the block effect (Snedecor and Cochran, 1981). Both summary statistical procedures used the same blocked two-way analysis of variance model.

Steer performance data were analyzed by analysis of covariance of a one-way treatment structure with initial weight being the covariate (Snedecor and Cochran, 1981). In trial 1 and 2 feed intake and feed effficiencies were not statistically analyzed due to the group feeding of the steers per treatment. Average daily gains were analyzed by individual animal within a pen (treatment). The summary statistics for the steer performance data for all three trials were pooled to be analyzed as a weighted block analysis of covariance of a one-way treatment structure using number of pens/treatment as the weight factor, trial as block effect, and initial weight as the covariate (Snedecor and Cochran, 1981).

RESULTS

Trial 1: Chemical analyses of the three forage sorghum silages from the concrete stave silos are shown in table 14. All three silages were well preserved and had undergone lactic acid fermentations. Compositions of the control and Sila-bac silages were similar; but LSA-100 silage had a higher pH and more ammonia-nitrogen. The addition of 15.6 kg of LSA-100/ 907 kg of fresh crop raised the CP content of the silage 4.84 percentage units above the original forage. This represents a 95.4% recovery of the supplemental nitrogen.

Actual ensiling temperature and ensiling temperature rise expressed as change from initial forage temperature are shown in figures 2 and 3,

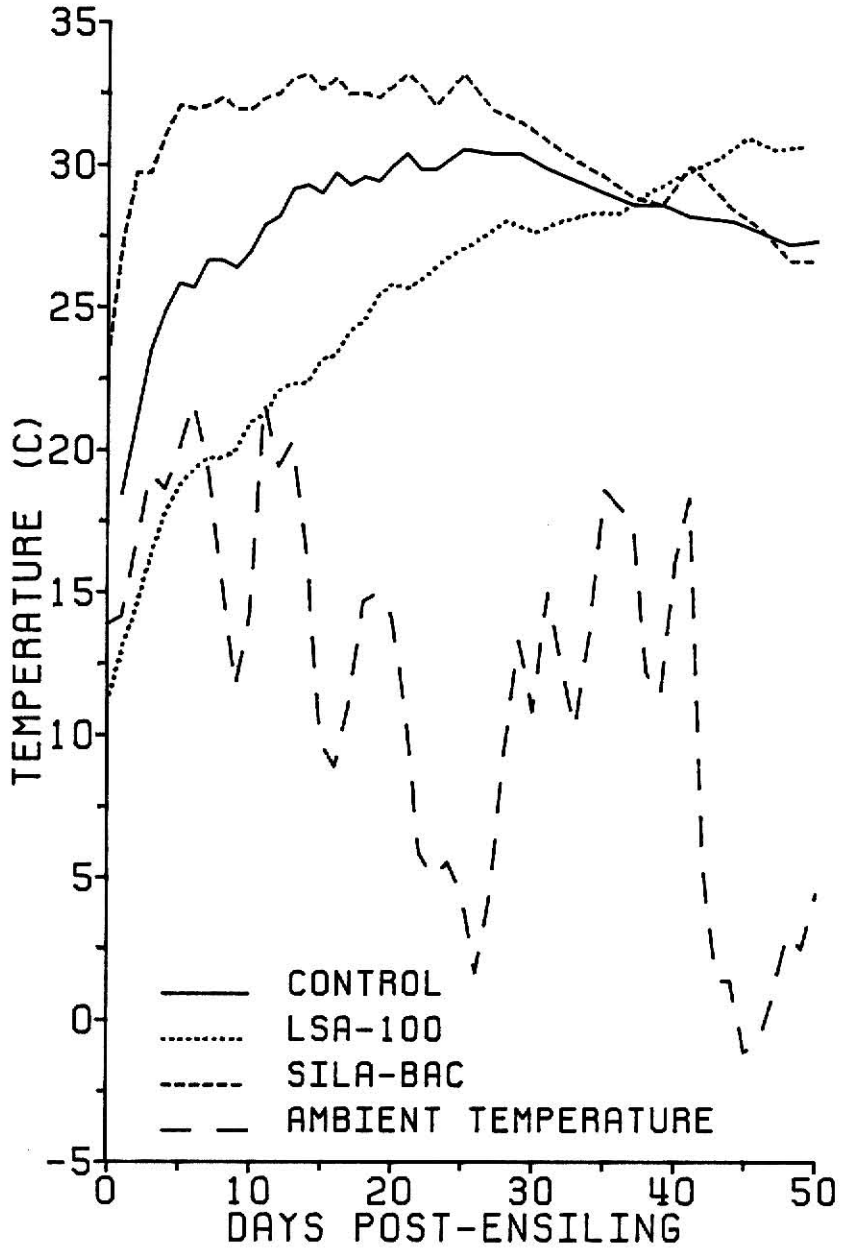


Figure 2. Ensiling temperatures for the control, LSA-100, and Sila-bac silages, trial 1.

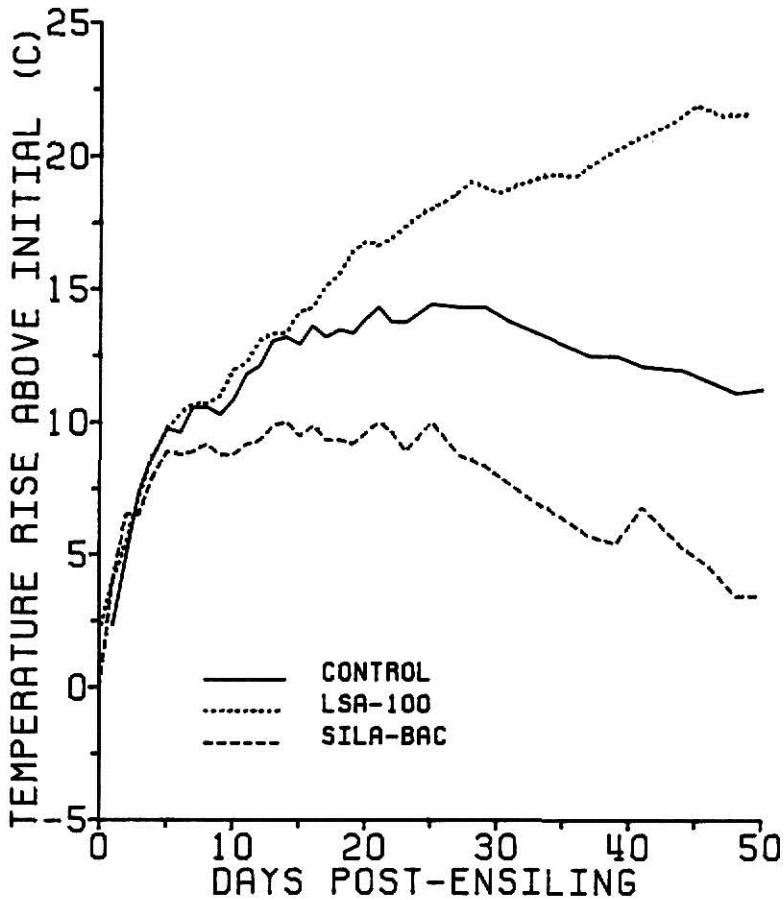


Figure 3. Temperature rise above initial ambient for the three forage sorghum silages, trial 1.

respectively. Sila-bac silage had the fastest temperature rise, peaking in 5 d at 10 C above its initial temperature. LSA-100 silage showed a slow, steady increase in temperature over the 50 d ensiling period, reaching a maximum of 22 C above its initial temperature; while the control silage peaked at 15 C above its initial temperature in 12 days. The initial temperature of the LSA-100 forage was 8 C compared with 15 and 22 C for the control and Sila-bac forages, respectively. This was due to differences in the ambient temperature when the silos were filled.

TABLE 14. Chemical analyses of the three forage sorghum silages made in concrete stave silos, trial 1.[1,2]

Item	Silage		
	Control	LSA-100	Sila-bac
Dry matter, %	29.08	30.53	30.13
pH	3.92	4.03	3.92
	% of the DM		
Crude protein	7.19	12.03	7.08
Crude fiber	23.19	22.40	23.09
Ether extract	2.97	2.99	2.94
Ash	7.98	7.93	7.91
Nitrogen-free extract	60.27	54.66	58.99
Lactic acid	4.47	4.40	4.82
Acetic acid	2.05	2.12	1.78
Propionic acid	TR	ND	ND
Butyric acid	TR	TR	ND
Total fermentation acids	6.62	6.62	6.71
	% of the total N		
Hot water insoluble-N	54.70	58.55	55.06
Ammonia-N	3.39	17.41	4.85

[1] Each value is the mean of six composited samples.
[2] TR means trace amounts; ND means none detected.

The silages in the nylon bags were well preserved and underwent lactic acid fermentations with the exception of LSA-100 silage which exhibited both a lactic and an acetic acid fermentations (table 15). The control and Sila-bac silages had numerically higher lactic acid and hot water insoluble-nitrogen levels than LSA-100 silage while LSA-100 had the

TABLE 15. Chemical analyses of the three forage sorghum silages made in nylon bags, trial 1.[1,2]

Item	Silage		
	Control	LSA-100	Sila-bac
Dry matter, %	27.50	28.52	29.58
pH	3.79	3.97	3.75
	% of the DM		
Crude protein	7.95	12.46	7.91
Crude fiber	22.81	22.71	22.81
Ether extract	4.89	3.45	4.09
Ash	7.86	8.12	7.72
Nitrogen-free extract	56.49	53.24	57.82
Lactic acid	5.77	4.70	5.66
Acetic acid	2.78	4.04	2.83
Propionic acid	.37	.25	.47
Butyric acid	.03	TR	TR
Total fermentation acids	8.98	9.01	8.99
	% of the total N		
Hot water insoluble-N	44.66	29.36	41.62
Ammomia-N	5.61	16.12	5.52

[1]Each value is the mean of six nylon bags.
[2]TR means trace amounts.

numerically highest acetic acid and ammonia-nitrogen levels. The silages in the nylon bags underwent more extensive fermentations than surrounding silage in the stave silos. Nylon bag silages from each of the three treatments had lower pH, hot water insoluble-nitrogen, and nitrogen-free extract values; and higher levels of lactic, acetic, propionic, and total fermentation acids compared with corresponding silages in the stave silos.

The 20 l container silages were also well preserved and all had undergone lactic acid fermentations (table 16). LSA-100 silage had the most extensive fermentation as indicated by numerically higher lactic and total fermentation acids and lower hot water insoluble-nitrogen values than the control or Sila-bac silages. The LSA-100 silage had a higher ($P<.05$) ammonia-nitrogen than the control or Sila-bac silages.

In table 17 is a summary of the fermentation characteristics on which nonlinear comparisons were evaluated. The additive-treated silage models for lactic and acetic acids and pH were not different ($P>.05$) from the control

TABLE 16. End-product silage chemical analyses of the three forage sorghum silages made in 20 l containers, trial 1.[1,2]

Item	Silage		
	Control	LSA-100	Sila-bac
Dry matter, %	28.46	28.83	29.35
pH	3.99	3.96	3.91
	% of the DM		
Crude protein	7.14[a]	8.99[b]	7.16[a]
Crude fiber	23.73	22.16	22.36
Ether extract	2.17	2.34	2.22
Ash	7.72	7.44	7.57
Nitrogen-free extract	59.25	59.07	60.69
Lactic acid	6.16	8.09	6.17
Acetic acid	2.49	3.31	2.97
Propionic acid	ND	ND	ND
Butyric acid	ND	ND	ND
Total fermentation acids	8.65	11.43	9.16
	% of the total N		
Hot water insoluble-N	49.42	37.61	50.83
Ammonia-N	2.43[a]	12.24[b]	4.00[a]

[1]Each value is the mean of two containers at 122 d post-ensiling.
[2]ND means none detected.
[a,b]$P<.05$.

TABLE 17. Models used to describe the ensiling characteristic dynamics of the forage sorghum silages, trial 1.[1]

Item	Model[2]	Significance[3]
Dry matter recovery	decay	P<.05
Lactic acid	growth	NS
Acetic acid	growth	NS
Total fermentation acids	growth	P<.05
Ammonia-nitrogen	growth	P<.05
Hot water insoluble-nitrogen	combination	P<.05
pH	decay	NS

[1]Control silage curves vs. treated silage curves.
[2]Refer to Appendix A for model description.
[3]NS means not significant.

silage while dry matter recovery, total fermentation acids, hot water insoluble-nitrogen, and ammonia-nitrogen were ($P<.05$). Parameter estimates, residual sum of squares, and degrees of freedom needed for model comparisons are shown in Appendix B (tables 1 thru 7). The significant portion of the confidence intervals for the models declared significantly different by the

nonlinear comparison technique are shown in table 18. Dry matter recoveries were greater ($P<.05$) for LSA-100 and Sila-bac silages than the control (75 to 122 d and 41 to 122 d, respectively), while LSA-100 and Sila-bac had similar ($P>.05$) dry matter recoveries. Sila-bac silage had less ($P<.05$) total fermentation acids than did the control or LSA-100 silages (2 to 4 d and 10 to 122 d, respectively), while the control and LSA-100 silage had similar ($P>.05$) levels. LSA-100 silage had higher ($P<.05$) ammonia-nitrogen and lower ($P<.05$) hot water insoluble-nitrogen values than control or Sila-bac silages for all 122 days.

TABLE 18. Significant portions of the confidence intervals about the difference between treatments for significant nonlinear models, trial 1.[1,2]

Item	Control vs. LSA-100	Control vs. Sila-bac	LSA-100 vs. Sila-bac
Dry matter loss	< 75 to 122	< 41 to 122	NS
Total fermentation acids	NS	> 2 to 4	> 10 to 122
Ammonia-nitrogen	< 0 to 122	NS	> 0 to 122

[1]In days post-ensiling.
[2]NS means not significant.

Dry matter recoveries and losses from the concrete stave silos, nylon bags, and containers are shown in table 19. Sila-bac silage lost numerically less dry matter during fermentation, storage, and feedout from the stave silos than the control and LSA-100 silages which were numerically similar. Non-feedable spoilage, which was the subjective removal of spoiled, moldy silage from the top of each silo on December 22, 1980, represented approximately 5% of the dry matter ensiled for all treatments.

Dry matter losses from the nylon bags were numerically less for LSA-100 and Sila-bac silages (10.9 and 11.0%, respectively) than for the control (13.4%). Both additives increased dry matter recovery in the 20 l containers

TABLE 19. Forage sorghum silage recoveries and losses from the concrete stave and experimental silos, trial 1.

Silo and silage treatments	DM recovered: Feedable	DM recovered: Non-feedable (spoilage)	DM lost during fermentation, storage, and feedout
	% of the DM ensiled		
Concrete stave			
Control	78.05	5.03	16.92
LSA-100	77.28	5.23	17.49
Sila-bac	81.16	4.85	13.99
Nylon bags[1]			
Control	86.65	----	13.35
LSA-100	89.11	----	10.89
Sila-bac	88.97	----	11.03
20 l containers[2]			
Control	86.55	----	13.45[b]
LSA-100	92.08	----	7.92[a]
Sila-bac	91.03	----	8.97[a]

[1]Each value is the mean of six bags.
[2]Each value is the mean of two containers at 122 d post-ensiling.
[a,b] P<.05.

TABLE 20. Forage sorghum silage temperature changes and losses of dry matter during air exposure, trial 1.[1]

Silage	Day of initial rise above ambient temp.[2]	Maximum temp., C	Accumulated temperature: 3	5	9	13	DM loss: 3	5	9	13
			C				% of DM exposed			
Control	3	35.0	17.2	61.1	102.5	113.9	8.75	13.42	16.43	21.69
LSA-100	7	40.0	ND	.7	33.0	175.4	<1.0	<1.0	3.90	22.24
Sila-bac	7	35.5	ND	ND	57.4	126.8	<1.0	<1.0	6.66	14.93

[1]ND means none detected.
[2]A 1.7 C rise or higher.

approximately 5 percentage units compared with dry matter recovered for the control silage.

Shown in table 20 are the aerobic stability characteristics of the three forage sorghum silages from the stave silos. The control silage was less stable upon air exposure than were the additive silages. It heated on d 3,

losing 8.8% of its original dry matter, and by the time both additive silages had begun to heat, the control silage had lost more than 16% of its dry matter.

In the steer growing trial, LSA-100 silage supported 7% faster gains than the control and 9% faster gains ($P<.05$) than Sila-bac silage (table 21). Feed intake was numerically highest for LSA-100 silage; lowest for Sila-bac silage. Feed efficiency was improved slightly for additive silages over the control silage (LSA-100, 1.9%; Sila-bac 4.2%).

TABLE 21. Performance by steers fed the three forage sorghum silage diets, trial 1.

Item	Silage diet		
	Control	LSA-100	Sila-bac
Number of steers	15	15	15
Initial wt., kg	232.3	229.9	229.1
Final wt., kg	325.0	332.2	322.5
Average daily gain, kg	1.16[ab]	1.26[b]	1.14[a]
Average daily feed intake, kg[1]			
sorghum silage	5.90	6.16	5.57
soybean meal	.50	.20	.50
grain sorghum	---	.30	---
premix[2]	.10	.10	.10
ground limestone	.05	.05	.05
ammonium sulfate	.04	.04	.04
total	6.59	6.85	6.26
Feed/kg of gain, kg[1]	5.75	5.64	5.51

[1]100% dry matter basis.
[2]Premix supplied 30,000 IU vitamin A, 300 mg monensin, 90 mg Tylan, 5 mg cobalt, 30 mg copper, 7 mg iodine, 150 mg iron, 100 mg manganese, and 272 mg zinc per steer daily.
[a,b] $P<.05$.

Presented in table 22 are the results of the voluntary intake, digestibility, and nitrogen balance trial with lambs. The voluntary dry matter intakes were similar ($P>.05$) and on the order of 3% of the lamb's body weight. Crude fiber and crude protein digestibilities were similar ($P>.05$) for all five diets. Dry matter digestibility was lower ($P<.05$) for the

control+urea diet than LSA-100 silage diet, but both were similar (P>.05) to the other three silage diets.

Nitrogen intake and nitrogen retained, both expressed as g/d, were similar (P>.05) for all five silage diets. Nitrogen retained when expressed as a percentage of the total intake nitrogen were similar (P>.05) for control+SBM, LSA-100 silage, and Sila-bac silage diets. When the LSA-100 was applied at the time of feeding to the control silage, nitrogen retained (as a percentage of the total intake nitrogen) was improved (P<.05) over LSA-100

TABLE 22. Voluntary intake, digestibility, and nitrogen balance for the five forage sorghum silage diets fed to lambs.[1]

	Diet				
	Control silage				
Item	+SBM	+urea	+LSA-100	LSA-100 silage	Sila-bac silage
Voluntary dry matter intake, g/d[2]	922.9	883.0	973.3	1032.4	1080.8
	% digestibility				
Dry matter	63.0^{ab}	59.0^{a}	59.9^{ab}	64.3^{b}	62.1^{ab}
Crude fiber	57.0	54.6	53.6	52.8	52.4
Crude protein	60.4	58.4	58.3	63.6	61.2
	Nitrogen balance				
Intake, g/d	18.0	17.2	18.9	19.0	21.7
Retained, g/d	2.1	-.6	5.0	1.5	4.4
Retained as % of total N	11.8^{b}	-3.0^{a}	24.7^{c}	7.5^{ab}	20.2^{bc}
Retained as % of absorbed N	19.6^{b}	-6.3^{a}	45.2^{c}	10.5^{ab}	32.8^{bc}

[1]Each value is the mean of five lambs.
[2]Voluntary intake for 7 days.
^{a,b,c} P<.05.

applied at the time of ensiling. In comparisons of the source of supplemental nitrogen for the control silage, the control+urea diet had less (P<.05) nitrogen retained as a percentage of the total intake nitrogen than control+SBM or control+LSA-100 diets. Nitrogen retained, as a percentage of absorbed nitrogen (biological value), followed a similar trend of

significance as nitrogen retained as a percentage of total intake nitrogen.

Trial 2: Chemical analyses of the two forage sorghum silages from the concrete stave silos are shown in table 23. Both silages were well preserved and had undergone lactic acid fermentations. The control silage had numerically higher nitrogen-free extract and hot water insoluble-nitrogen; while LSA-100 had higher pH, lactic, acetic, and total fermentation acids; and ammonia-nitrogen. The addition of 16.2 kg of LSA-100/ 907 kg of fresh crop raised the CP content of the silage 4.36 percentage units above the original forage. This represents a 90.9% recovery of the supplemental nitrogen.

TABLE 23. Chemical analyses of the two forage sorghum silages made in concrete stave silos, trial 2.[1]

Item	Silage	
	Control	LSA-100
Dry matter, %	29.11	29.23
pH	4.01	4.21
	% of the DM	
Crude protein	8.29	12.65
Crude fiber	22.28	22.38
Ether extract	3.05	3.23
Ash	8.15	8.20
Nitrogen-free extract	58.21	53.54
Lactic acid	4.98	5.50
Acetic acid	3.07	3.28
Propionic acid	.01	.01
Butyric acid	.04	.07
Total fermentation acids	8.19	8.99
	% of the total N	
Hot water insoluble-N	61.02	43.77
Ammonia-N	4.59	20.77

[1]Each value is the mean of nine composited samples.

Actual ensiling temperature and ensiling temperature rise expresses as change from initial forage temperature are shown in figures 4 and 5, respectively. LSA-100 silage had the fastest temperature rise, peaking in 3 d at 7.5 C above its initial temperature, while the control silage peaked at 5.0 C above its initial temperature in 6 days.

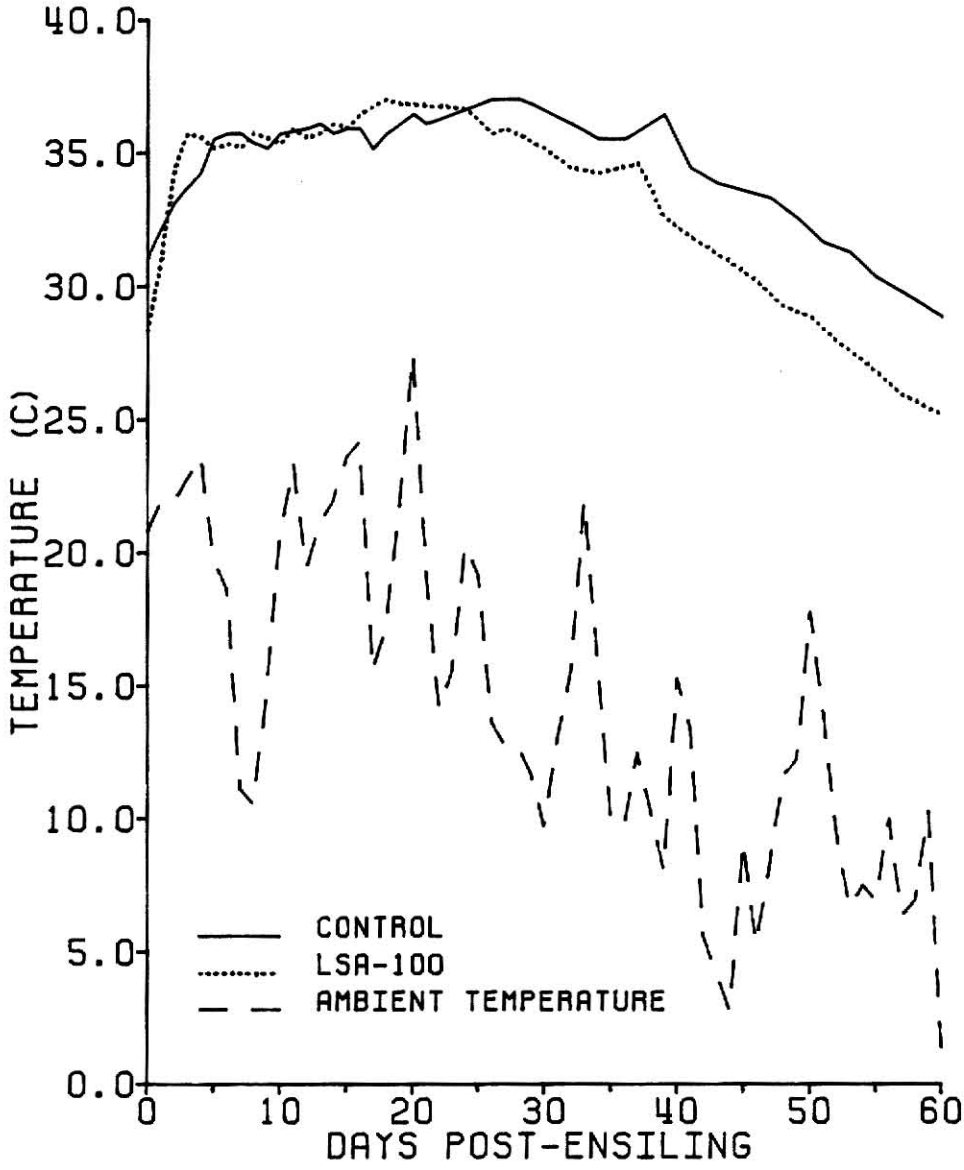


Figure 4. Ensiling temperature for the control and LSA-100 silages, trial 2.

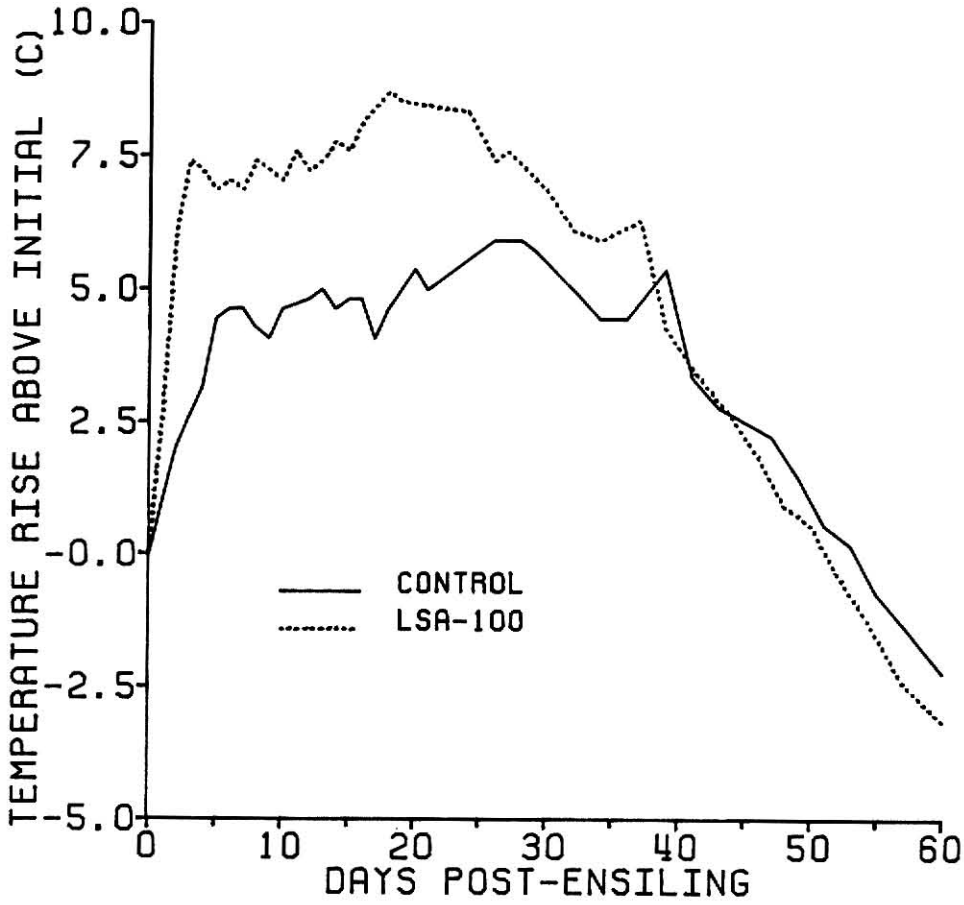


Figure 5. Temperature rise above initial ambient for the two forage sorghum silages, trial 2.

The 20 l container silages were also well preserved and both silages had undergone an extensive lactic acid fermentation (table 24). The LSA-100 silage had higher ($P<.05$) crude protein, pH, and ammonia-nitrogen values, while crude fiber and hot water insoluble-nitrogen were lower ($P<.05$) than the control silage.

TABLE 24. End-product silage chemical analyses of the two forage sorghum silages made in 20 l containers, trial 2.[1,2]

Item	Silage: Control	Silage: LSA-100
Dry matter, %	29.47	29.53
pH	3.77[a]	3.90[b]
	% of the DM	
Crude protein	8.10[a]	14.15[b]
Crude fiber	21.67[b]	18.36[a]
Ether extract	3.77	2.59
Ash	9.32	7.72
Nitrogen-free extract	57.30	57.20
Lactic acid	8.00	9.09
Acetic acid	2.23	2.26
Propionic acid	TR	TR
Butyric acid	TR	TR
Total fermentation acids	10.42	11.49
	% of the total N	
Hot water insoluble-N	50.72[b]	39.40[a]
Ammonia-N	4.81[a]	15.10[b]

[1]Each value is the mean of six containers at 160 d post-ensiling.
[2]TR means trace amounts.
[a,b] $P<.05$.

TABLE 25. Forage sorghum silage recoveries and losses from the concrete stave and experimental silos, trial 2.

Silo and silage treatments	DM recovered: Feedable	DM recovered: Non-feedable (spoilage)	DM lost during fermentation, storage, and feedout
	% of the DM ensiled		
Concrete stave			
Control	79.98	1.90	18.12
LSA-100	75.99	3.44	20.57
20 l containers[1]			
Control	96.55	----	3.45
LSA-100	96.53	----	3.47

[1]Each value is the mean of six containers at 160 d post-ensiling.

Dry matter recoveries and losses from the concrete stave silos and containers are shown in table 25. The LSA-100 silage lost 2.45 percentage units more dry matter than the control during fermentation, storage, and feedout. Non-feedable spoilage was greater for the LSA-100 silage. In the 20 l containers, both the control and LSA-100 silages lost minimal dry matter during fermentation and storage.

Shown in tables 26, 27, and 28 are the aerobic stability characteristics of the three forage sorghum silages from the stave silos. In the first measurement (table 26), both silages were unstable when exposed to air. In the two subsequent measurements (tables 27 and 28) both silages became increasingly more stable with LSA-100 silage being more stable than the

TABLE 26. Forage sorghum silage temperature changes and losses of dry matter during air exposure, trial 2, Number 1.[1]

Silage	Day of initial rise above ambient temp.[2]	Maximum temp., C	Accumulated temperature, Days of air exposure: 2	4	6	DM loss: 2	4	6
			C			% DM exposed		
Control	2	42.4	19.6	60.9	71.5	2.33	11.11	ND
LSA-100	1	47.0	27.4	61.6	73.9	7.92	16.18	ND

[1]ND means not determined.
[2]A 1.7 C rise or higher.

TABLE 27. Forage sorghum silage temperature changes and losses of dry matter during air exposure, trial 2, Number 2.[1,2]

Silage	Day of initial rise above ambient temp.[3]	Maximum temp., C	Accumulated temperature, Days of air exposure: 3	9	22	DM loss: 3	9	22
			C			% DM exposed		
Control	3	42.9	4.25	76.3	ND	1.18	11.77	ND
LSA-100	NR	NR	NR	NR	NR	3.90	3.27	4.09

[1]ND means not determined.
[2]NR means no temperature rise.
[3]A 1.7 C rise or higher.

TABLE 28. Forage sorghum silage temperature changes and losses of dry matter during air exposure, trial 2, Number 3.

Silage	Day of initial rise above ambient temp.[1]	Maximum temp., C	Days of air exposure: Accumulated temperature 5	8	13	DM loss 5	8	13
			C			% of DM exposed		
Control	6	40.0	0	43.1	97.1	<1.0	2.92	8.73
LSA-100	9	23.0	0	1.4	11.8	<1.0	<1.0	<1.0

[1]A 1.7 C rise or higher.

control as indicated by less heating and lower dry matter losses upon exposure to air.

In the steer growing trial, LSA-100 silage produced similar gains (P>.05) when compared to the control silage fed with SBM as the source of supplemental nitrogen (table 29). Feed intake was 5% less for the LSA-100 silage than for the control but feed efficiency was improved by 11%.

TABLE 29. Performance by steers fed the two forage sorghum silage diets, trial 2.

Item	Silage diet: Control	LSA-100
Number of steers	15	15
Initial wt., kg	227.1	228.3
Final wt., kg	322.7	323.2
Average daily gain, kg	.85	.89
Average daily feed intake, kg[1]		
sorghum silage	5.63	5.35
soybean meal	.83	.20
grain sorghum	---	.63
premix[2]	.09	.09
ground limestone	.05	.05
ammonium sulfate	.04	.04
total	6.67	6.36
Feed/kg of gain, kg [1]	8.11	7.22

[1]100% dry matter basis.
[2]Premix supplied 30,000 IU vitamin A, 300 mg monensin, 90 mg Tylan, 5 mg cobalt, 30 mg copper, 7 mg iodine, 150 mg iron, 100 mg manganese, and 272 mg zinc per steer daily.

Trial 3: Chemical analyses of the three forage sorghum silages from the concrete stave silos are shown in table 30. The control and 1177 silages underwent a restricted lactic acid fermentation as indicated by the relatively high pH and low lactic and total fermentation acid levels, while LSA-100 had the lowest lactic and highest acetic acid values. pH were numerically similar for the control and 1177 silages with LSA-100 being approximately one pH unit higher. The addition of 18.2 kg of LSA-100/ 907 kg of fresh crop raised the CP content of the silage 2.23 percentage units above the original forage. This represents a 86.2% recovery of the supplemental nitrogen.

TABLE 30. Chemical analyses of the three forage sorghum silages made in concrete stave silos, trial 3.[1,2]

Item	Silage		
	Control	LSA-100	1177
Dry matter, %	43.67	42.41	42.92
pH	4.48	5.66	4.75
	% of the DM		
Crude protein	10.11	12.34	9.72
Crude fiber	19.04	20.71	20.58
Ether extract	3.35	3.61	3.77
Ash	6.72	7.13	7.26
Nitrogen-free extract	60.79	56.22	58.67
Lactic acid	2.99	2.68	3.13
Acetic acid	1.28	2.30	1.28
Propionic acid	.01	.01	.01
Butyric acid	TR	TR	TR
Total fermentation acids	4.30	5.04	4.44
	% of the total N		
Hot water insoluble-N	67.74	62.58	69.69
Ammonia-N	2.10	38.11	4.99

[1]Each value is the mean of five composited samples.
[2]TR means trace amounts.

Actual temperature and ensiling temperature rise expressed as change from initial forage temperature are shown in figures 6 and 7, respectively. The LSA-100 silage had a fast, steady temperature rise over the 18 d

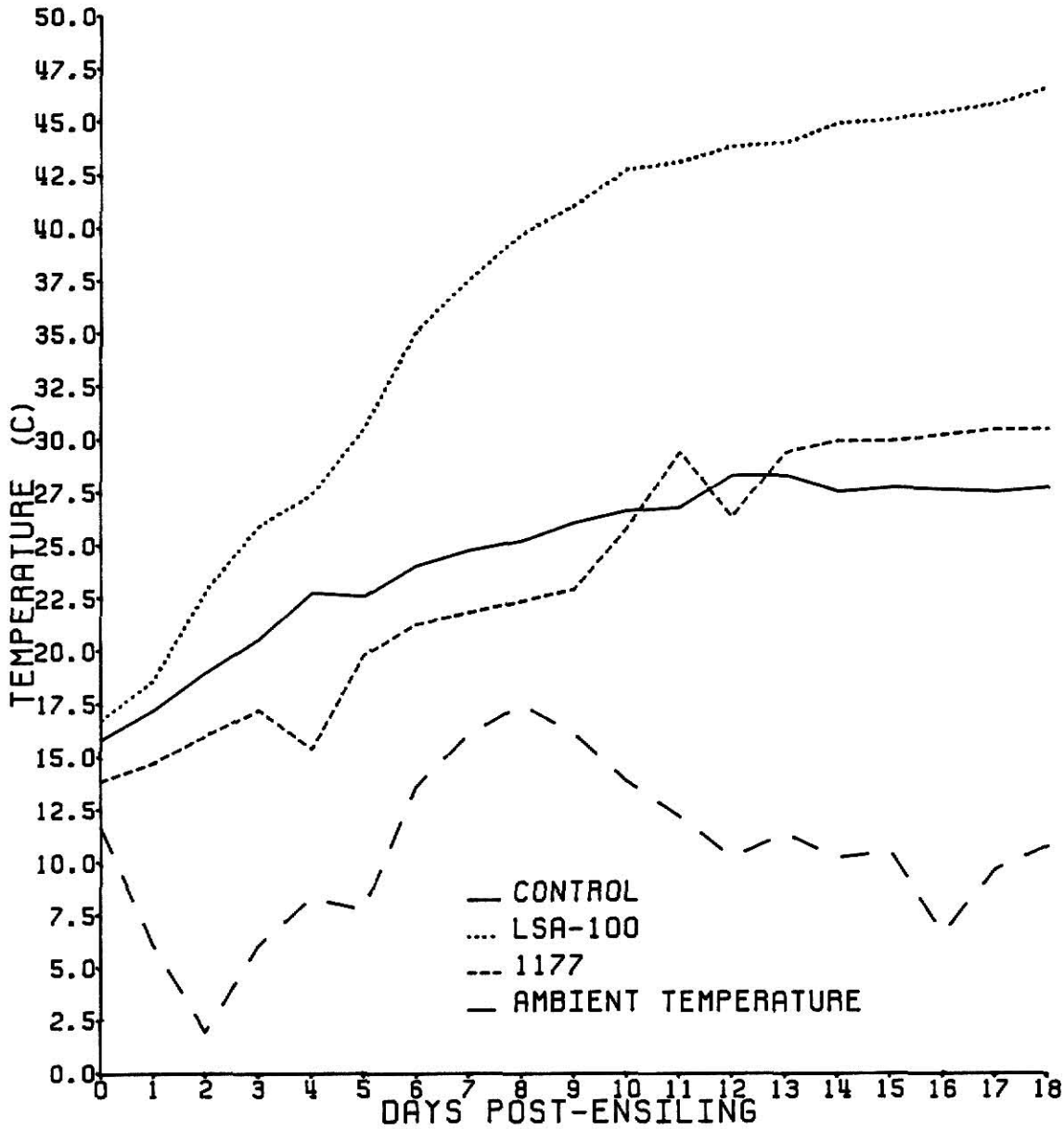


Figure 6. Ensiling temperature for the control, LSA-100, and 1177 silages, trial 3.

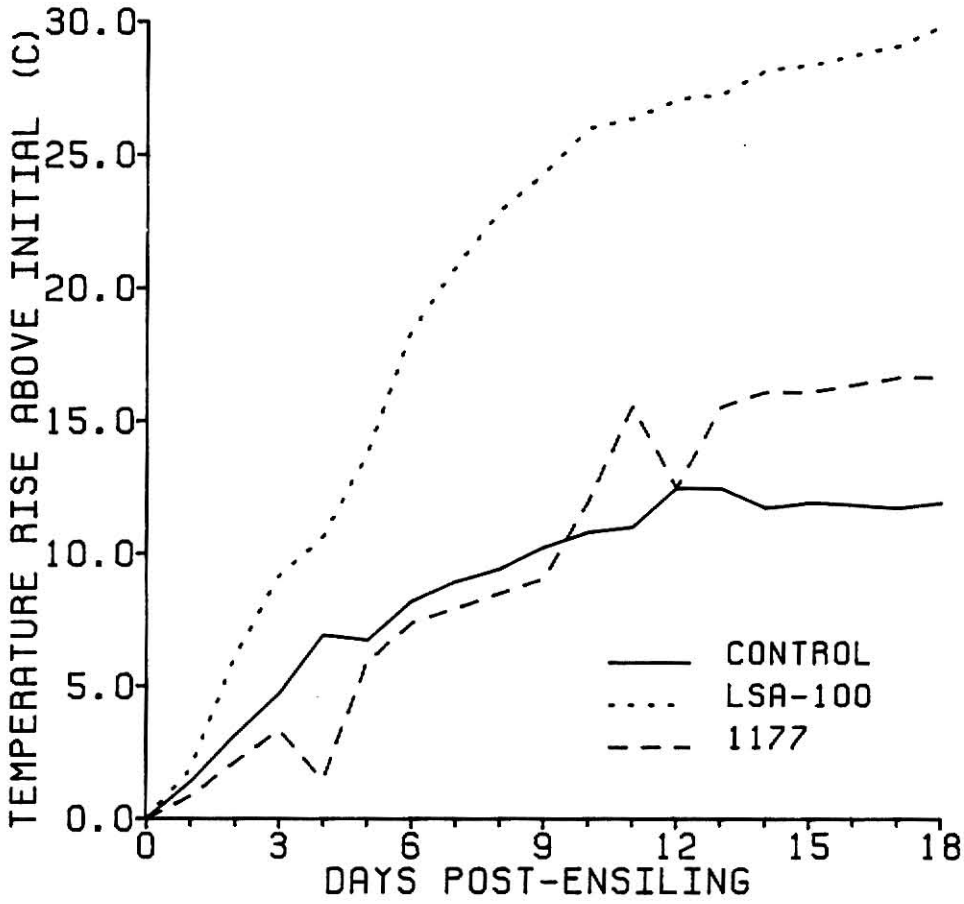


Figure 7. Temperature rise above initial ambient for the three forage sorghum silages, trial 3.

monitoring period while the control and 1177 silages had a much slower increasing temperature.

The silages in the nylon bags were well preserved and underwent more extensive fermentations than the surrounding silage in the stave silos (table 31). pH were lower in the nylon bags than in the stave silos for all three silage treatments. The LSA-100 silage had the highest lactic, acetic, and total fermentation acids and highest ammonia-nitrogen. Hot water insoluble-nitrogen values were similar to the stave silages, except for the LSA-100 silage which showed a much lower value in the nylon bags.

TABLE 31. Chemical analyses of the three forage sorghum silages made in nylon bags, trial 3.[1,2]

Item	Silage		
	Control	LSA-100	1177
Dry matter, %	44.29	41.99	43.93
pH	4.41	5.01	4.82
	% of the DM		
Crude protein	9.89	13.37	10.53
Crude fiber	21.32	22.54	17.74
Ether extract	4.15	3.67	2.81
Ash	7.49	7.68	6.48
Nitrogen-free extract	57.15	52.74	62.45
Lactic acid	3.66	4.54	3.93
Acetic acid	1.27	3.19	.84
Propionic acid	.01	TR	.01
Butyric acid	.06	TR	TR
Total fermentation acids	5.01	7.75	4.80
	% of the total N		
Hot water insoluble-N	62.44	46.07	65.74
Ammonia-N	3.61	19.74	2.66

[1]Each value is the mean of six nylon bags.
[2]TR means trace amounts.

The 20 l container silages were well preserved and all had undergone lactic acid fermentations (table 32). The fermentations were more extensive than the in nylon bags and stave silos as indicated by the lower pH and generally higher lactic and total fermentation acid contents. The LSA-100 silage had the highest ($P<.05$) pH, total fermentation acids, and

TABLE 32. End-product silage chemical analyses of the three forage sorghum silages made in 20 l containers, trial 3.[1,2]

Item	Silage		
	Control	LSA-100	1177
Dry matter, %	43.67	42.41	42.92
pH	4.13[a]	4.59[b]	4.14[a]
	% of the DM		
Crude protein	9.32[a]	13.50[b]	9.89[a]
Crude fiber	19.82	19.06	19.74
Ether extract	3.41	3.34	3.71
Ash	6.49	7.74	7.19
Nitrogen-free extract	60.85	56.36	59.43
Lactic acid	3.25	4.12	4.55
Acetic acid	2.46	2.82	2.27
Propionic acid	.02[a]	.09[b]	.03[a]
Butyric acid	TR	TR	TR
Total fermentation acids	5.75[a]	7.03[b]	6.86[a]
	% of the total N		
Hot water insoluble-N	73.58[c]	50.45[a]	60.94[b]
Ammonia-N	2.74[a]	15.98[b]	4.43[a]

[1]Each value is the mean of six containers at 70 d post-ensiling.
[2]TR means trace amounts.
[a,b,c] $P<.05$.

ammonia-nitrogen values while the control and 1177 were similar ($P>.05$). Hot water insoluble-nitrogen was different ($P<.05$) for the three silages with the control being the highest and LSA-100 the lowest. The addition of 18.1 kg of LSA-100/ 907 kg of fresh crop raised the CP content 4.18 percentage units above the original forage. This represents a 99.8% recovery of the supplemental nitrogen in the 20 l containers.

In table 33 is a summary of the fermentation characteristics on which nonlinear comparisons were evaluated. The additive-treated silage models for dry matter recovery and acetic acid were not different ($P>.05$) from the control silage while lactic and total fermentation acids; ammonia- and hot water insoluble-nitrogen; and pH were ($P<.05$). Parameter estimates, residual sum of squares, and degrees of freedom needed for model comparisons are shown in Appendix B (tables 8 thru 14). The significant portion of the confidence

TABLE 33. Models used to describe the ensiling characteristic dynamics of the forage sorghum silages, trial 3.[1]

Item	Model[2]	Significance[3]
Dry matter recovery	decay	NS
Lactic acid	growth	P<.05
Acetic acid	growth	NS
Total fermentation acids	growth	P<.05
Ammonia-nitrogen	growth	P<.05
Hot water insoluble-nitrogen	decay	P<.05
pH	decay	P<.05

[1]Control silage curves vs. treated silage curves.
[2]Refer to Appendix A for model description.
[3]NS means not significant.

intervals for the models declared significantly different by the nonlinear comparison technique are shown in table 34. Lactic acid content was higher (P<.05) for 1177 silage than the control (6 to 70 d) while both 1177 and control silages were similar (P<.05) to LSA-100 silage. The total fermentation acid content was lower (P<.05) for the control than 1177 and LSA-100 (10 to 70 d and 26 to 70 d, respectively) while 1177 and LSA-100 were similar (P>.05). The LSA-100 silage had a higher ammonia-nitrogen values than the control or 1177 silages (0 to 8 d and 0 to 5 d, respectively) and LSA-100 silage also had a lower (P<.05) hot water insoluble-nitrogen than the

TABLE 34. Significant portions of the confidence intervals about the difference between treatments for significant nonlinear models, trial 3.[1,2]

Item	Control vs. LSA-100	Control vs. 1177	LSA-100 vs. 1177
Lactic acid	NS	< 6 to 70	NS
Total fermentation acids	< 26 to 70	< 10 to 70	NS
Ammonia-nitrogen	< 0 to 8	NS	> 0 to 5
Hot water insoluble-nitrogen	> 0 to 70	NS	NS
pH	< 0 to 70	NS	> 0 to 70

[1]In days post-ensiling.
[2]NS means not significant.

control for all 70 days. 1177 silage had similar (P>.05) hot water insoluble-nitrogen compared with the control and LSA-100 silages. The LSA-100 silage had a higher (P<.05) pH than the control and 1177 for the entire trial, while the control and 1177 were similar (P>.05).

Dry matter recoveries and losses from the concrete stave silos, nylon bags, and 20 l containers are shown in table 35. The LSA-100 silage lost numerically more dry matter than the control during fermentation, storage, and feedout from the stave silos while 1177 silage lost numerically less dry matter. Non-feedable spoilage represented approximately 4.5 to 5.5 % of the dry matter ensiled for all of the treatments.

TABLE 35. Forage sorghum silage recoveries and losses from the concrete stave and experimental silos, trial 3.

Silo and silage treatments	DM recovered: Feedable	DM recovered: Non-feedable (spoilage)	DM lost during fermentation, storage, and feedout
	% of the DM ensiled		
Concrete stave			
Control	84.39	4.41	11.20
LSA-100	76.22	5.47	18.31
1177	87.04	5.77	7.19
Nylon bags[1]			
Control	96.70	----	3.30
LSA-100	95.53	----	4.47
1177	96.66	----	3.34
20 l containers[2]			
Control	96.66	----	3.34
LSA-100	95.58	----	4.42
1177	96.86	----	3.14

[1]Each value is the mean of six bags, except LSA-100, mean of four bags.
[2]Each value is the mean of six containers at 70 d post-ensiling.

Dry matter loss from the nylon bags was numerically highest for LSA-100 silage and similar for the control and 1177 silages. Losses from the 20 l containers followed a similar trend as the nylon bags but losses were statistically similar (P<.05).

Shown in tables 36 and 37 are the aerobic stability characteristics of the three forage sorghum silages from the stave silos. The first measument showed that all three silages were highly unstable when exposed to air. The second measurement showed that the additive silages were slightly more stable in air than the control silage with LSA-100 being the most stable.

TABLE 36. Forage sorghum silage temperature changes and losses of dry matter during air exposure, trial 3, Number 1.[1]

Silage	Day of initial rise above ambient temp.[2]	Maximum temp., C	Days of air exposure: Accumulated temperature 2	4	8	DM loss 2	4	8
			C			% DM exposed		
Control	1	50.8	24.1	71.2	133.2	3.57	10.38	ND
LSA-100	1	40.7	25.2	53.0	76.5	4.45	9.80	ND
1177	1	43.8	18.9	59.7	114.4	4.52	8.72	ND

[1]ND means not determined.
[2]A 1.7 C rise or higher.

TABLE 37. Forage sorghum silage temperature changes and losses of dry matter during air exposure, trial 3, Number 2.[1]

Silage	Day of initial rise above ambient temp.[2]	Maximum temp., C	Days of air exposure: Accumulated temperature 2	4	8	DM loss 2	4	8
			C			% DM exposed		
Control	1	37.4	19.6	52.8	86.9	3.24	9.06	ND
LSA-100	4	34.5	<1.0	2.5	33.7	1.20	4.07	ND
1177	2	33.0	7.4	24.9	72.4	1.59	6.83	ND

[1]ND means not determined.
[2]A 1.7 C rise or higher.

In the steer growing trial, the LSA-100 silage produced a faster ($P<.05$) average daily gain than 1177 silage but both silages were similar ($P>.05$) to the control silage (table 38). Feed intake was highest ($P<.05$) for the

TABLE 38. Performance by steers fed the three forage sorghum silage diets, trial 3.

Item	Silage diet		
	Control	LSA-100	1177
Number of steers	12	11	11
Initial wt., kg	219.6	220.9	223.8
Final wt., kg	263.9	271.2	266.4
Average daily gain, kg	.79[ab]	.90[b]	.75[a]
Average daily feed intake, kg[1]			
sorghum silage	4.64	5.11	4.38
soybean meal	.91	.23	.91
grain sorghum	.04	.73	.04
premix[2]	.03	.03	.03
ground limestone	.03	.03	.03
total	5.65[a]	6.12[b]	5.39[a]
Feed/kg of gain, kg[1]	7.23	7.21	7.18

[1]100% dry matter basis.
[2]Premix consisted of salt, 56.9%; trace mineral salt, 8.6%; and tallow, 34.5% providing 30,000 IU vitamin A and 150 mg monensin per steer daily.
[a,b] $P<.05$.

LSA-100 silage. Feed efficiencies were numerically and statistically similar ($P>.05$) for all three silage diets.

Discussion

In trial 3, the forage sorghum silages were 12 to 13 percentage units drier than the silages in trials 1 and 2. These differences in dry matter were due to a killing frost which occurred prior to harvesting the forage sorghum in trial 3. Slower and less extensive fermentations occurred in the drier silages, as indicated by the higher pH values, lower lactic and total fermentation acids contents, and prolonged temperature rises. Murdoch (1960) noted that high dry matter forages were difficult to consolidate sufficiently to prevent overheating and molding. Stirling (1951) and McDonald et al. (1962) reported that wilting of forages delayed anaerobic bacterial multiplication within the ensiled mass, especially lactobacilli and gram-negative microorganisms, which allowed prolonged plant respiration and a

large population of aerobic microorganisms. This might explain the extended temperature rises observed in the drier silages in trial 3. Numerous reseachers (Nash, 1959; Jackson and Forbes, 1970; McDonald, 1981) have reported that increasing the dry matter content of the forage restricts silage fermentation and results in silages with higher pH and residual water soluble carbohydrates (WSC); lower levels of lactic and acetic acids; and no butyric acid. Hinds et al. (1982b) ensiled alfalfa at three moisture levels 69.5, 63.5, and 44.0 percent. They found that the low moisture silage had the highest pH value and lowest fermentation acids.

The drier silages in trial 3 were less stable in air than the wetter sorghum silages in trials 1 and 2. Woolford (1978) attributed the reduced aerobic stability of the low moisture silages to increased populations of aerobic microorganisms and the higher levels of residual water soluble carbohydrates. Huber et al. (1968) reported that the aerobic microorganisms have a longer time to proliferate due to the increased amounts of entrapped oxygen which results from reduced consolidation in the low moisture forage mass. These microorganisms go dormant once the forage mass becomes anaerobic but they are re-activated when the silage is subsequently exposed to air. Ruxton et al. (1975) noted that carbohydrate rich forages, those retaining high levels of residual WSC either by chemically restricted fermentation or wilting, were particularly prone to aerobic deterioration at the time of feeding.

Recovery of the supplemental nitrogen in the LSA-100 silage was lower in trial 3 (86.6%) than trials 1 and 2 (95.4 and 90.9%, respectively). Bolsen et al. (1980) observed a low recovery (49%) of Cold-flo nitrogen when applied to high dry matter (42-46%) corn silage. They concluded that the relatively low recovery was probably due to the lack of sufficient moisture to absorb the released ammonia from the Cold-flo. Bolsen and Ilg, (1981) applied Cold-flo (1.8% on a DM basis) to wet (32-35% DM) forage sorghum silage and

noted that the recovery of supplemental nitrogen was 76.3% of the total nitrogen applied which was considerably lower than the results with LSA-100 in all three trials. Huber et al. (1979) applied Pro-Sil (2% on a DM basis) to low dry matter (32-34%) corn silage and noted an 88% recovery of the supplemental nitrogen. This recovery was more in line with nitrogen recoveries in trials 1 and 2, likely because of the similar composition of Pro-Sil and LSA-100 (ie., molasses, NPN, and minerals).

A 3-trial summary of selected chemical components and dry matter recoveries of the forage sorghum silages made in the concrete stave silos, nylon bags, and 20 l containers is shown in table 39. The only interaction ($P<.05$) between silo type and silage treatment was for dry matter recovery. This resulted from Sila-bac/1177 silages having higher ($P<.05$) dry matter recoveries in the stave silos compared with control and LSA-100 silages, while silages from the three treatments had similar recoveries in the nylon bags and 20 l containers.

TABLE 39. Summary of the dry matter recoveries of the three forage sorghum silages made in the concrete stave silos, nylon bags, and 20 l containers for the three trials.

Silo and silage treatments	DM recovered[1]
Concrete stave	
Control	84.59[ab]
LSA-100	81.21[a]
Sila-bac/1177	90.23[c]
Nylon bags	
Control	92.50[bc]
LSA-100	93.14[bc]
Sila-bac/1177	93.64[bc]
20 l containers	
Control	94.07[c]
LSA-100	94.36[c]
Sila-bac/1177	94.72[c]

[1] % of the DM ensiled.
[a,b,c] $P<.05$.

The main effects of silo type and silage treatment are shown in table 40. The higher levels of lactic acid ($P<.05$), lactic:acetic acid ratios, and dry matter recoveries ($P<.05$) in the experimental silos also suggest these silos produced more efficient, homofermentative fermentations than the concrete stave silos and that ensiling conditions for the stave silos were less than ideal. Wilson and Wilkins (1972) made silages in 100 g test-tube silos, 6 kg polyethene bags, and 1000 kg PVC bags and compared fermentation characteristics. They concluded that the experimental silos represented "ideal" ensiling conditions which are difficult to achieve at the farm-scale and that the results should not be extended beyond the pilot-scale silos (300-2000 kg capacity). Hingston and Christensen (1982) ensiled cereal grains (31-40% DM) in 100-tonne farm-scale bunker silos and compared chemical compositions with silages made in 1.1 x 1.8 m pilot-scale experimental silos. They noted that the pH values of the silage from the bunker silos were slightly higher than those found in the corresponding experimental silos. They concluded that silo type had no significant affect on chemical composition of the silages and that the pilot-scale silos produced silage similar to farm-scale silos which were managed under "ideal" conditions.

TABLE 40. Summary of the chemical analyses of the forage sorghum silages for the three trials by silo type and by silage treatment.

Silo type	pH	Lactic acid	Acetic acid	Total acid
		---------% of the DM--------		
Concrete stave	4.33^{a}	4.45^{a}	2.04^{a}	6.60^{a}
Nylon bag	4.19^{a}	5.75^{b}	2.39^{ab}	8.40^{b}
20 l container	3.96^{b}	6.40^{b}	2.57^{b}	9.06^{b}
Silage treatment				
Control	4.01^{a}	5.21	2.18^{a}	7.55^{a}
LSA-100	4.39^{b}	5.57	2.95^{b}	8.65^{b}
Sila-bac/1177	4.08^{a}	5.81	1.88^{a}	7.85^{ab}

[1]Total fermentation acids.
^{a,b} $P<.05$.

TABLE 40 (cont.). Summary of the chemical analyses and dry matter recoveries of the forage sorghum silages for the three trials by silo type and by silage treatment.

Silo type	Hot water insoluble-N	NH_3-N	DM recovered[2]	Lactic: acetic acid
	---% of total N---			
Concrete stave	59.19[a]	11.07[a]	85.34[a]	2.27
Nylon bag	47.40[b]	8.37[a]	93.09[b]	2.92
20 l container	46.32[b]	8.88[a]	94.38[b]	2.57
Silage treatment				
Control	55.92[a]	3.85[a]	90.39[a]	2.49[a]
LSA-100	43.43[b]	20.16[b]	89.57[a]	2.03[a]
Sila-bac/1177	53.56[a]	4.30[a]	92.86[b]	3.24[b]

[2]% of the DM ensiled.
[a,b] $P<.05$.

El Hag et al. (1982) also found that laboratory silos yielded silages of superior quality to farm-scale silos as indicated by lower pH and ammonia-nitrogen values and higher lactic acid contents.

The silages inoculated with Sila-bac/1177 had similar pH values, total fermentation acids, and hot water insoluble- and ammonia-nitrogen values as the controls. However, the ratio of lactic:acetic acid was significantly higher in Sila-bac/1177 silages than in control silages, suggesting a more homofermentative fermentation with inoculants. This coincided with a significant increase in dry matter recoveries in inoculated silages over the control silages. These results agree with sorghum silage data of Bolsen and Ilg (1981a) and Rakshit and Voelker (1981).

The LSA-100 treated silages underwent the most extensive fermentations as indicated by the highest total fermentation acids. Huber et al. (1968) observed similar results when .5% urea was added to corn silage at 30, 36, and 44% dry matter. The higher fermentation acids were likely due to the additional buffer capacity from the increased ammonia-nitrogen in the LSA-100 silages. Hot water insoluble-nitrogen, when expressed as a percent of total nitrogen, suggests that the addition of LSA-100 caused a reduction in hot

water insoluble-nitrogen. Actually, when the values are expressed as a percentage of the dry matter, the LSA-100 silages retained the highest levels of nitrogen in the insoluble form which was likely a result of decreased proteolysis (Huber et al., 1979 and Johnson et al., 1982). Goering and Waldo (1981), in a review of NPN additions to whole-plant corn forages at the time of ensiling, noted that additions of ammonia reduced the insoluble nitrogen disappearance during ensiling over the control forages while urea did not prevent the nitrogen solubilization. The lactic:acetic acid ratio was lower in LSA-100 silages compared with the controls which indicate that LSA-100 resulted in a shift towards a heterofermentative fermentation. Although LSA-100 altered the fermentation pattern, it did not lower dry matter recovery as might have been expected from the less efficient fermentation pathways (McDonald, 1981).

The dynamics of the fermentation characteristics in the 20 l containers were affected by initial dry matter content and the additions of LSA-100 and Sila-bac/1177. The drier silages (trial 3) showed greater differences in fermentation characteristics due to treatment than did the wetter silages (trial 1). However, all silages in trial 1 were well preserved reguardless of treatment and there were fewer silo observations/treatment in trial 1 than trial 3. In trial 3, LSA-100 and 1177 increased total fermentation acids (26 to 70 d and 10 to 70 d post-ensiling, respectively) over the control; 1177 by increasing lactic acid and LSA-100 by increasing all fermentation acids. Hinds et al. (1982a) used the same procedure for nonlinear model comparisons to evaluate four commercially available inoculants/culture on alfalfa and whole-plant corn silage fermentations. They concluded that the 20 l containers produced excellent silages from both crops and that the nonlinear modeling was a useful statistical procedure for describing the difference in the dynamics of silage fermentation due to treatment. Results of trials 1 and 3 indicate that nonlinear models did indicate significant differences in

silage fermentation dynamics due to silage treatments.

A summary of performance by steers fed the forage sorghum silage diets for the three trials is shown in table 41. Feed intake was highest ($P<.05$) for the LSA-100 silages, while the intakes for the control and Sila-bac/1177 silages were similar. The increased intake for LSA-100 silage disagrees with most research comparing NPN-treated silage to control silage supplemented with natural protein (Cash et al., 1971; Fox and Cook, 1976; Bolsen and Ilg, 1981a). There have been only a few trials which have shown an increased intake with NPN-treated silage (Henderson et al., 1971a; Cook and Fox, 1976; Huber et al., 1979). Numerous trials suggest that inoculants do not significantly affect corn or sorghum silage intakes by cattle compared with the controls (Newland et al., 1979; Bolsen et al., 1980; Bolsen and Ilg, 1981b; Luther and Nothnagel, 1982).

TABLE 41. Summary of performance by steers fed the three forage sorghum silage diets for the three trials.

Item	Silage diet		
	Control	LSA-100	Sila-bac/1177
Average daily gain, kg	.94[ab]	1.05[b]	.91[a]
Average daily feed intake, kg[1]	7.16[a]	7.62[b]	6.89[a]
Feed/kg of gain, kg[1]	8.15	8.12	8.10

[1]100% dry matter basis.
[a,b] $P<.05$.

LSA-100 silages produced faster gains but similar feed efficiencies compared with Sila-bac/1177 and control silages which were supplemented with soybean meal. Part of the advantage in weight gain for LSA-100 silage was due to the control and Sila-bac silage diets in trial 1 being only 10.1% CP while the LSA-100 diet was 12.7% crude protein. Bolsen et al. (1978) evaluated protein levels for forage sorghum silage diets fed to calves and found that those fed 10% CP diets gained slower and less efficiently than those fed 12 or 14 % CP diets.

The increase in cattle gains from LSA-100 silage agrees with Cash et al. (1971) who applied Pro-Sil (2.25% on a DM basis) to corn silage (31-36% DM) and found faster ($P<.05$) gains than the control silage supplemented with soybean meal. Most research evidence shows that NPN-treated silages range from no difference to a depression in weight gains when compared with control silages supplemented with soybean meal (Henderson et al., 1971b,c; Cook and Fox, 1976; Bolsen and Ilg, 1981b). Several trials have shown that calves fed inoculated corn or sorghum silages had improved weight gains and feed efficiencies compared with those fed control silages (Newland et al., 1979; Bolsen et al., 1982; Luther and Nothnagel, 1982).

Results of the lamb digestion trial substanciate the performance of the steers in the growth trials. The lambs fed LSA-100 silage utilized the dietary nitrogen as well as lambs fed the control silage supplemented with soybean meal and better than lambs fed the control silage supplemented with urea. Steers fed LSA-100 silage had gains and feed efficiencies similar to those fed control silage supplemented with soybean meal. The control silage supplemented with LSA-100 had the highest biological value for lambs; control silage supplemented with urea, the lowest. Since a deficiency of sulfur limited nitrogen retention in lambs (Barry et al., 1978), the high nitrogen:sulfur ratio (15:1) of the urea diet could partially explain the low nitrogen retention.

LITERATURE CITED

AOAC. 1965. Official Methods of Analysis (10th Ed.). Association of Official Agricultural Chemists. Washington, D. C.

AOAC. 1970. Official Methods of Analysis (11th Ed.). Association of Official Agricultural Chemists. Washington, D. C.

Barker, S. B. and W. H. Summerson. 1941. The colorimetric determination of latic acid in biological material. J. Biol. Chem. 138:535.

Barry, T. N., J. E. Cook, and R. J. Wilkins. 1978. The influence of formic acid and formaldehyde additives and type of harvesting machine on the utilization of nitrogen in lucerne silages. 1. The voluntary intake and nitrogen retention of young sheep consuming the silages with and without intraperitoneal supplements of DL-methionine. Agric. Sci. (Camb.) 91:701.

Bolsen, K. and H. Ilg. 1982. Drought-stressed and additive-treated corn silages for steers. Western Section Amer. Soc. Anim Sci. Proc. 33:90.

Bolsen, K., J. Oltjen, and H. Ilg. 1978. Milo stover, forage sorghum, and protein levels compared for growing calves. Agric. Exp. Sta. Report of Progress 320. p. 53. Kansas State University. Manhattan, Kansas.

Bolsen, K. K. and H. J. Ilg. 1981a. Inoculant, enzyme, NPN, or NaOH additives for corn and sorghum silages: fermentation and aerobic stability. J. Anim. Sci. 53:Suppl 1:382.

Bolsen, K. K. and H. J. Ilg. 1981b. Inoculant, enzyme, NPN, or NaOH additives for corn and sorghum silages: cattle performance. Anim. Sci. 53:Suppl 1:382.

Bolsen, K. K., H. J. Ilg, and D. E. Axe. 1980. Additives for corn silage. J. Anim. Sci. 51:Suppl 1:230.

Cash, E., H. E. Henderson, and W. G. Bergen. 1971. Corn silage additives and concentrate levels compared. Report of Beef Cattle Research AH-BC-704. p. 28. Michigan State University. East Lansing, Michigan.

Chatfield, C. and A. J. Collins. 1980. Introduction to Multivariate Analysis. Chapman and Hall. New York.

Conway, E. J. 1957. Microdiffusion Analysis and Volumetric Error. Chemical Publishing Co. New York.

Cook, R. J. and D. G. Fox. 1976. Anhydrous ammonia treated corn silage for feedlot cattle. Report of Beef Cattle Research AH-BC-7610. p. 96. Michigan State University. East Lansing, Michigan.

El Hag, M., R. L. Vetter, and M. D. Kenealy. 1979. Silage additives, moisture, and energy effects on the fermentation of alfalfa in model laboratory silos. J. Anim. Sci. 49:Suppl 1:365.

Fox, D. G. and R. J. Cook. 1976. Performance of steer calves fed corn silage treated with three sources of anhydrous ammonia. Report of Beef Cattle Research AH-BC-7609. p. 89. Michigan State University. East Lansing, Michigan.

Goering, H. K. and D. R. Waldo. 1981. Ammonia addition to whole-corn plant at ensiling. Maryland Nutr. Conf. Feed Manufacturers.

Goering, H. K. and P. S. Van Soest. 1970. Forage fiber analysis. Agr. Handbook No. 379.

Henderson, H. E., C. K. Allen, E. Cash, and W. G. Bergen. 1971a. Pro-Sil vs. soybean meal for supplementing 0%, 1/2%, 1%, 1 1/2%, and 2% concentrate rations. Report of Beef Cattle Research AH-BC-702. p. 5. Michigan State University. East Lansing, Michigan.

Henderson, H. E., D. R. Beattie, M. R. Geasler, and W. G. Bergen. 1971b. Molasses, minerals, ammonia, and Pro-Sil addition to corn silage for feedlot cattle. Report of Beef Cattle Research AH-BC-6950. p. 1. Michigan State University. East Lansing, Michigan.

Henderson, H. E., D. R. Beattie, M. R. Geasler, and W. G. Bergen. 1971c. Effect of level of Pro-Sil addition to corn silage on performance of yearling steers. Report of Beef Cattle Research AH-BC-6940. p. 15. Michigan State University. East Lansing, Michigan.

Hinds, M. A., H. J. Ilg, K. K. Bolsen, and G. A. Milliken. 1982a. Commercial additives for alfalfa and whole-plant corn silages. Western Section Amer. Soc. Anim. Sci. Proc. 33:312.

Hinds, M. A., K. K. Bolsen, and H. J. Ilg. 1982b. Alfalfa silages and hay and corn supplementation for steers. Amer. and Can. Soc. Anim. Sci. 1982 Meeting. p. 430 (Abstr.).

Hingston, A. R. and D. A. Christenson. 1982. The effect of type of silo and formic acid preservation on the nutritive value of barley, wheat and oat silages for growing Hereford steers. Can. J. Anim. Sci. 62:155.

Huber, J. T., C. E. Polan, and D. Hillman. 1968. Urea in high corn silage rations for dairy cattle. J. Anim. Sci. 27:220.

Huber, J. T., R. E. Lichtenwalner, R. E. Ledebuhr, and C. M. Hansen. 1979. Gaseous ammonia treatment of corn silage for dairy cows. J. Dairy Sci. 62:965.

Jackson, N. and T. J. Forbes. 1970. The voluntary intake by cattle of four silages differing in dry matter content. Anim. Prod. 12:591.

Johnson, C. O. L. E., J. T. Huber, and W. G. Bergen. 1982. Influence of ammonia treatment and time of ensiling on proteolysis in corn silage. J. Dairy Sci. 65:1740.

Luther, R. M. and J. Nothnagel. 1982. Untreated and microbial inoculated corn silage in high silage rations for beef steers. 1982 Cattle Feeders Day. p. 1. South Dakota State Unversity. Brookings, South Dakota.

McDonald, P. 1981. The Biochemistry of Silage. John Wiley and Sons. New York.

Milliken, G. A. and R. L. DeBruin. 1978. A procedure to test hypotheses for nonlinear models. Communications in Statistics--Theory and methods ATCD. p. 65-79.

Murdoch, J. C. 1960. The effect of pre-ensiling herbage on the composition of silage and its intake by cows. J. Br. Grassl. Soc. 15:70.

Nash, M. J. 1959. Partial wilting of grass crops for silage: 2. Experimental silages. J. Br. Grassl. Soc. 14:107.

Newland, H. W., F. M. Byers, and D. Reed. 1979. Probiotic treated corn silage, processing high moisture corn, and housing effects on finishing heifer calves. 1979 Ohio Beef Cattle Research. p. 32. Progress Report Series 79-1. Ohio State University. Columbus, Ohio.

Rakshit, C. C. and H. H. Voelker. 1981. Effects of additives on preservation of alfalfa silage, corn silage, and corn stillage. J. Dairy Sci. 64:115 (Abstr.).

Ruxton, I. B., B. J. Clark, and P. McDonald. 1975. A review of the effects of oxygen on ensilage. J. Br. Grassl. Soc. 30:23.

Snedecor, G. W. and W. G. Cochran. 1981. Statistical Methods (7th ed.). Iowa State University Press. Ames, Iowa.

Stirling, A. C. 1951. Bacterial changes in experimental laboratory silage. Proc. Soc. Appl. Bact. 14:151.

Wilson, R. F. and R. J. Wilkins. 1972. An evaluation of laboratory ensiling techniques. J. Sci. Food Agric. 23:377.

Woolford, M. K. 1978. The aerobic deterioration of silage. Agric. Res. Council Res. Review 4:8.

APPENDIX

APPENDIX A

There are several different processes involved in the dynamics of silage fermentation--as some characteristics increase (grow) over time; some characteristics decrease (decay) over time; and some characteristics decrease and then increase, or increase and then decrease, over time (combination). Although there are numerous mathematical models which could be used to describe the dynamics of the ensiling process, the three models used in these trials were, where t denotes time in days post-ensiling:

1. growth model -- $y= A+B(1-e^{-ct})+E$
2. exponential decay model -- $y=A+Be^{-ct}+E$
3. combination model -- $y=(At^2+Bt+1)/(t^2+C)+E$

The data collected for a single characteristic was plotted inorder to select the particular model that described it best. A nonlinear estimation procedure (SAS PROC NLIN, SAS USER's GUIDE, SAS Institue, 1979) was used to calculate the least squares estimates of the parameters of the selected model. The models for the treatments were compared over the range of the ensiling period (0 to 122 d in trial 1 and 0 to 70 d in trial 3) by using a model comparison technique (Milliken and DeBruin, 1978).

The technique involves, 1) selection of a model which best describes the data and fit the model to each treatment separately, and add the RESIDUAL SUM of SQUARES and the DEGREES of FREEDOM for the treatments forming the POOLED values. 2) Fit the model to the combined data across all treatments and determine the RESIDUAL SUM of SQUARES and DEGREES of FREEDOM for the COMBINED data. 3) The SUM of SQUARES due to the DIFFERENCE in the model is the COMBINED RESIDUAL SUM of SQUARES minus the POOLED RESIDUAL SUM of SQUARES and the DIFFERENCE DEGREES of FREEDOM are the appropriate COMBINED minus POOLED DEGREES of FREEDOM. 4) The test statistic is the DIFFERENCE RESIDUAL SUM of

SQUARES divided by the DIFFERENCE DEGREES of FREEDOM subsequently divided by the POOLED RESIDUAL SUM of SQUARES divided by POOLED DEGREES of FREEDOM. The models are declared significantly different if the test statistic exceeds and F percentage point with the appropriate degrees of freedom.

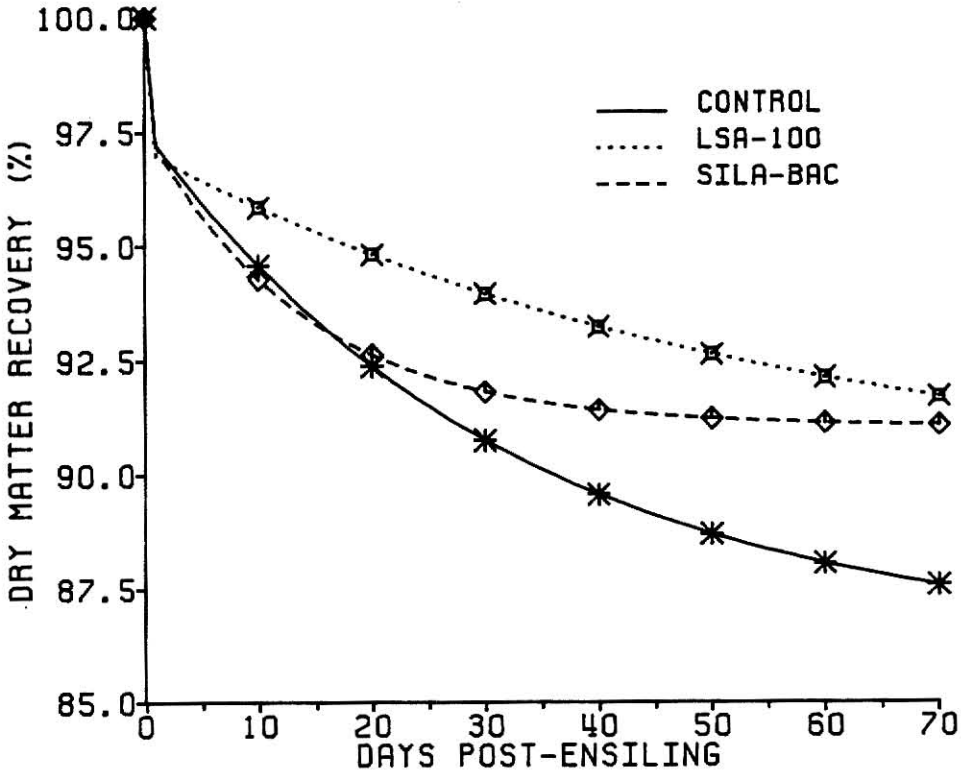
To determine where the treatment response curves were different, confidence intervals about the difference between the curves were computed for each day. The two curves were declared to be significantly different at a given day if the corresponding confidence interval did not contain zero.

APPENDIX B

APPENDIX TABLE 1. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of dry matter recovery dynamics, trial 1.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	86.29	11.29	.03	2.689	9
LSA-100	89.59	7.50	.02	22.895	9
Sila-bac	91.05	6.62	.07	9.964	9
Pooled data	---	---	---	35.547	27
Combined data	89.91	7.94	.06	57.929	33
Difference	---	---	---	22.382	6

$F=(22.382/6)/(35.547/27)=2.833$ $F_{.05}(6,27)=2.46$

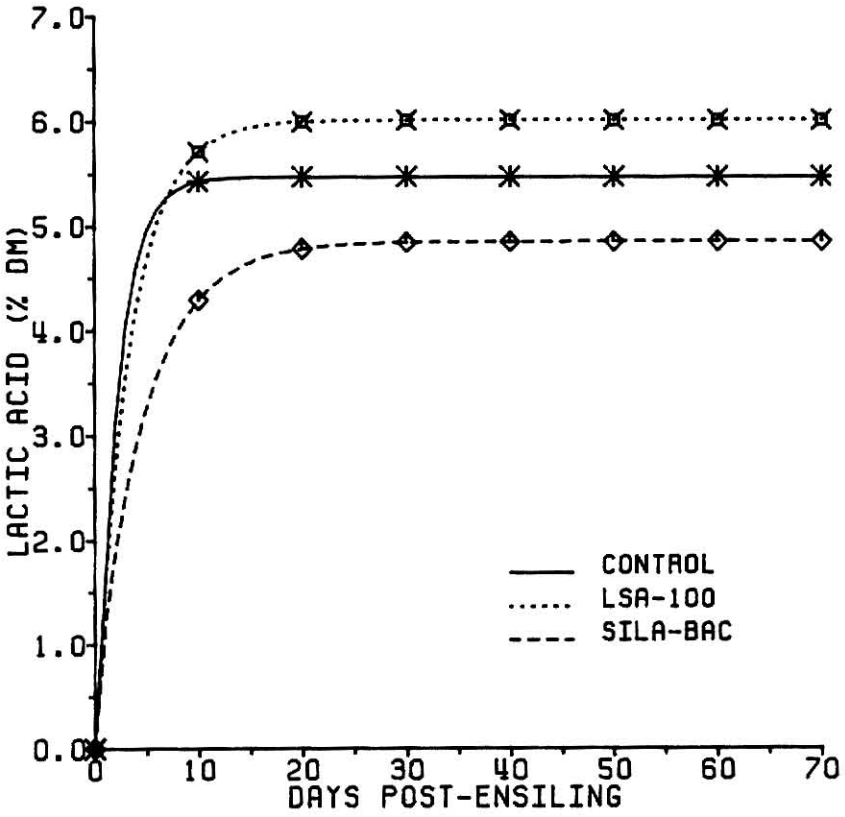


APPENDIX FIGURE 1. Model response curves for dry matter recovery dynamics (0-70 d), trial 1.

APPENDIX TABLE 2. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of lactic acid dynamics, trial 1.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	.064	-.010	.51	.0018	9
LSA-100	.060	.000	.30	.0007	9
Sila-bac	.045	.003	.21	.0002	9
Pooled data	---	---	---	.0028	27
Combined data	.051	.005	.26	.0389	33
Difference	---	---	---	.0011	6

$F=(.0011/6)/(.0028/27)=1.797$ $F_{.05}(6,27)=2.46$

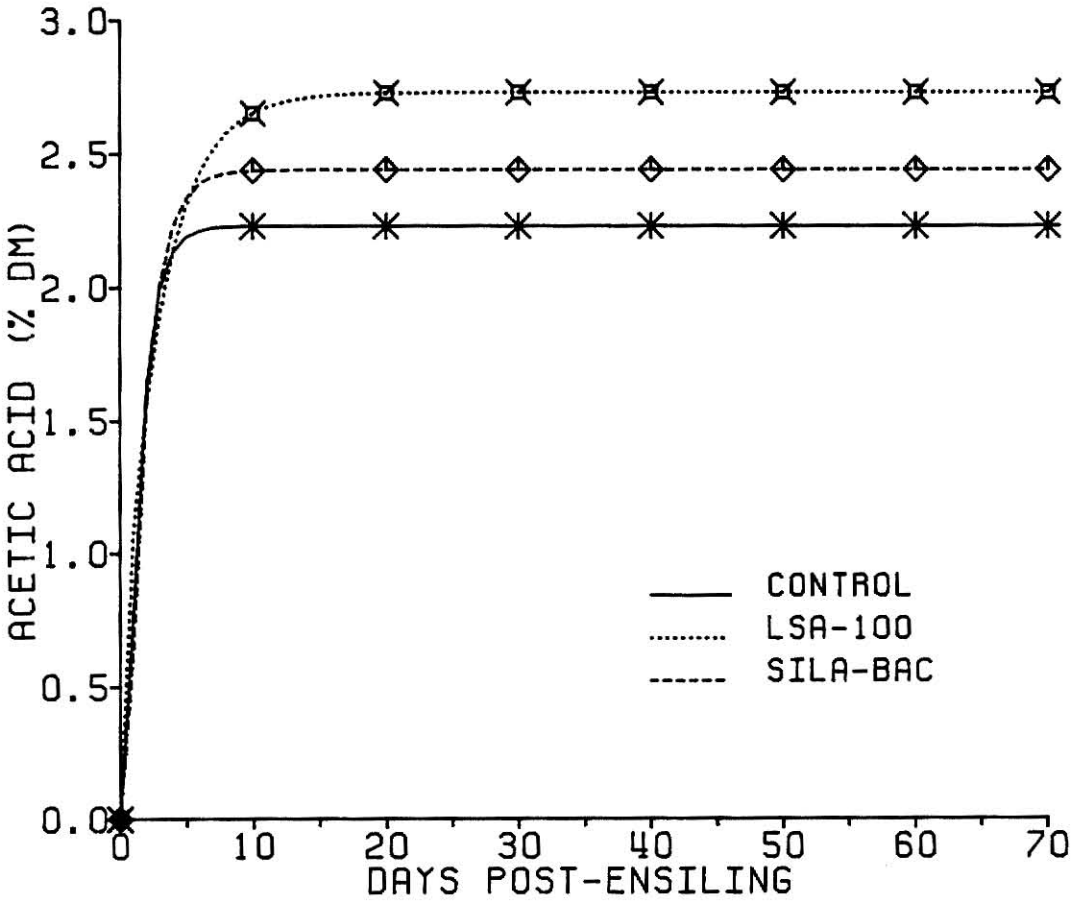


APPENDIX FIGURE 2. Model response curves for lactic acid dynamics (0-70 d), trial 1.

APPENDIX TABLE 3. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of acetic acid dynamics, trial 1.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	.036	-.0136	.90	.00004	9
LSA-100	.023	.0042	.34	.00002	9
Sila-bac	.037	-.0124	.71	.00010	9
Pooled data	---	---	---	.00017	27
Combined data	.0292	-.0046	.59	.00024	33
Difference	---	---	---	.00007	6

$F=(.00007/6)/(.00017/27)=1.848$ $F_{.05}(6,27)=2.46$

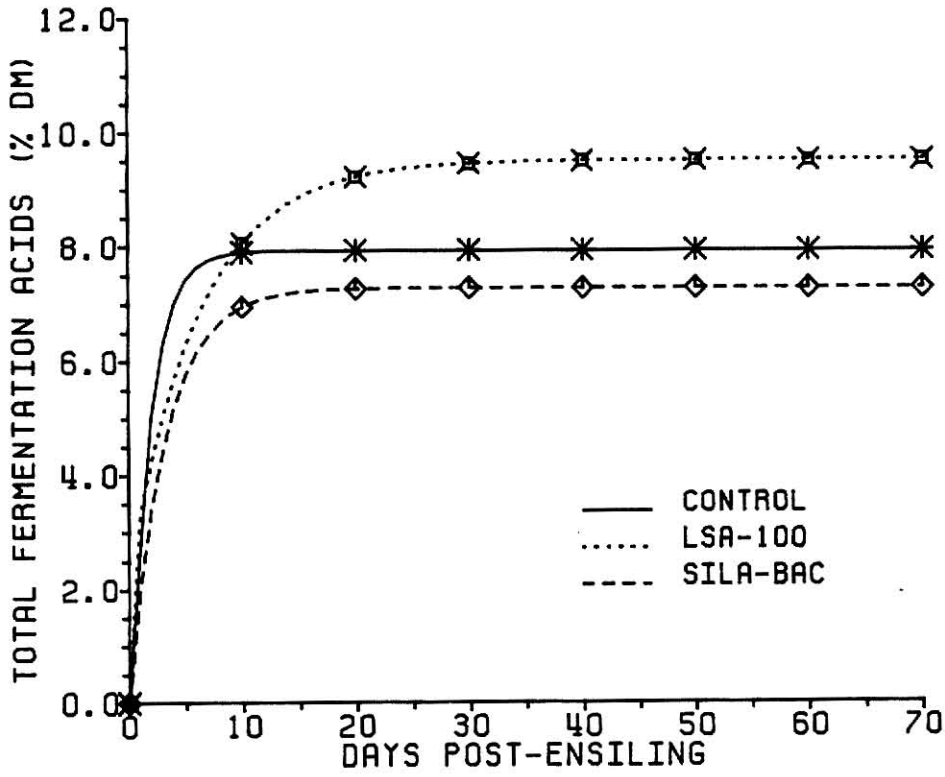


APPENDIX FIGURE 3. Model response curves for acetic acid dynamics (0-70 d), trial 1.

APPENDIX TABLE 4. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of total fermentation acids dynamics, trial 1.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	.094	-.0145	.58	.0020	9
LSA-100	.072	.0224	.16	.0004	9
Sila-bac	.072	.0006	.31	.0007	9
Pooled data	---	---	---	.0032	27
Combined data	.075	.0062	.32	.0051	33
Difference	---	---	---	.0020	6

$F=(.0020/6)/(.0032/27)=2.843$ $F_{.05}(6,27)=2.46$

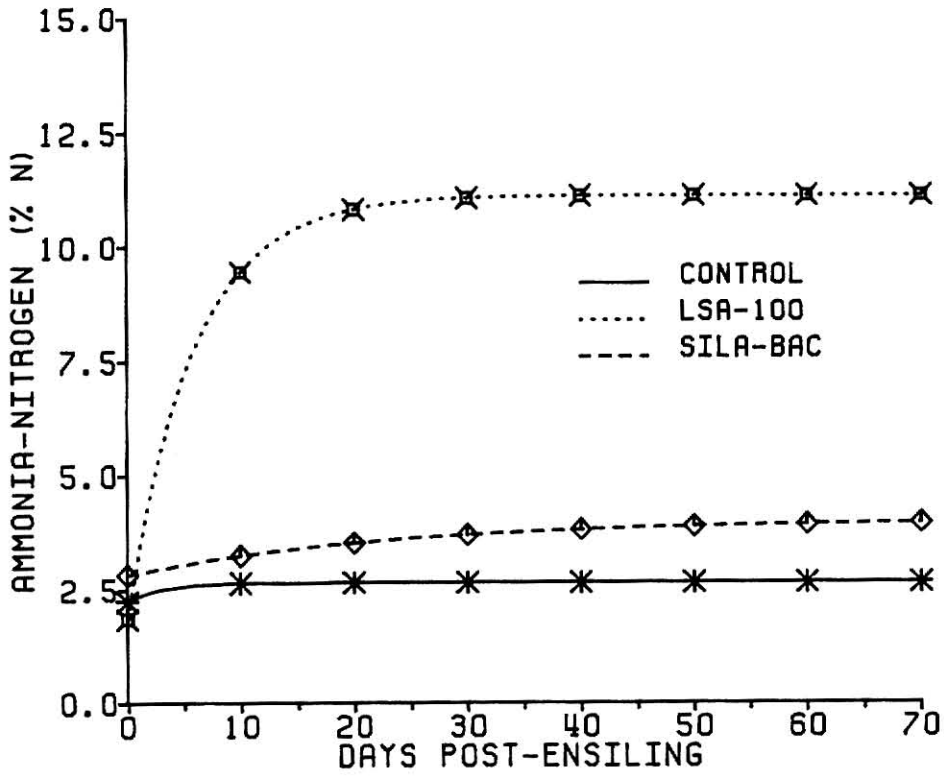


APPENDIX FIGURE 4. Model response curves for total fermentation acids dynamics (0-70 d), trial 1.

APPENDIX TABLE 5. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of ammonia-nitrogen dynamics, trial 1.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	.022	.0041	.35	.0001	8
LSA-100	.019	.0928	.17	.0024	9
Sila-bac	.028	.0119	.04	.0001	7
Pooled data	---	---	---	.0026	24
Combined data	.022	.0400	.10	.0549	30
Difference	---	---	---	.0523	6

$F=(.0523/6)/(.0026/24)=80.461$ $F_{.05}(6,24)=2.51$

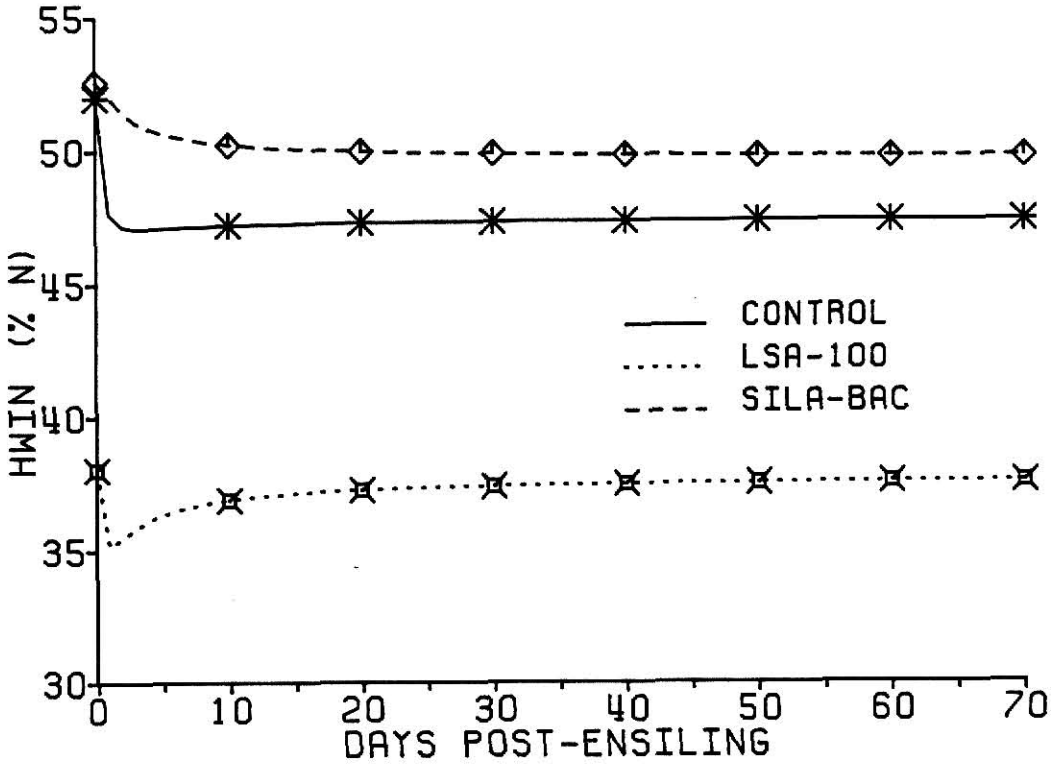


APPENDIX FIGURE 5. Model response curves for ammonia-nitrogen dynamics (0-70 d), trial 1.

APPENDIX TABLE 6. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of hot water insoluble-nitrogen dynamics, trial 1.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	47.43	-3.17	-.13	185.1	9
LSA-100	37.71	-9.81	-.24	105.7	8
Sila-bac	49.67	6.42	.09	96.4	9
Pooled data	---	---	---	387.2	26
Combined data	45.11	-1.21	-.05	1760.6	32
Difference	---	---	---	1373.4	6

$F=(1373.4/6)/(387.2/26)=15.370$ $F_{.05}(6,26)=2.47$

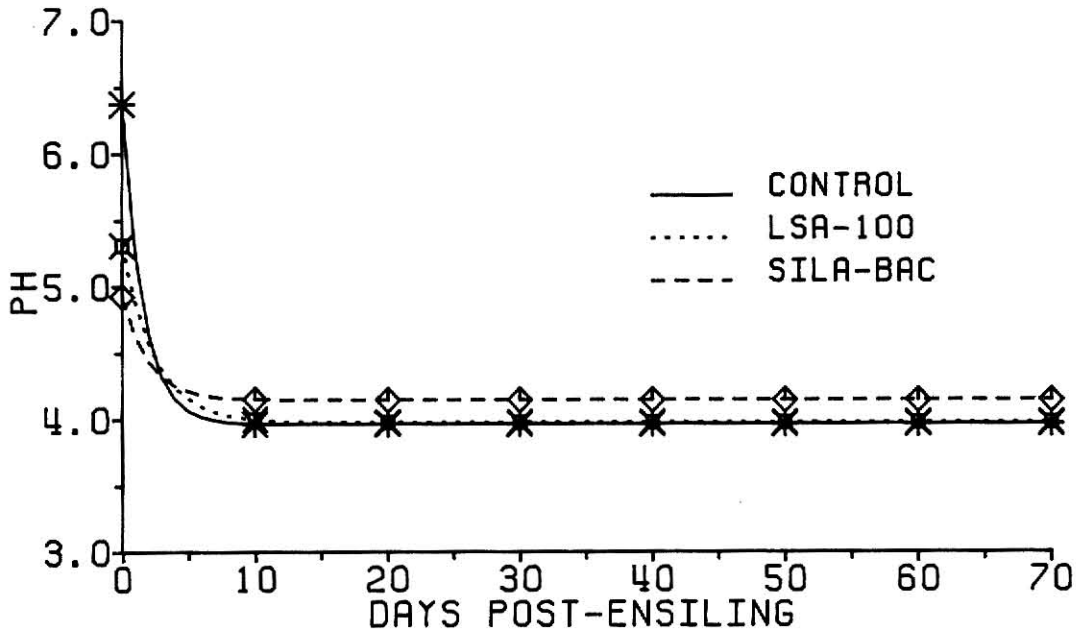


APPENDIX FIGURE 6. Model response curves for hot water insoluble-nitrogen dynamics (HWIN, 0-70 d), trial 1.

APPENDIX TABLE 7. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of pH dynamics, trial 1.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	3.966	2.409	.64	.187	9
LSA-100	3.977	1.337	.40	.091	9
Sila-bac	4.147	.783	.50	.811	8
Pooled data	---	---	---	1.089	26
Combined data	4.035	1.647	.57	1.507	32
Difference	---	---	---	.418	6

$F=(.418/6)/(1.089/26)=1.663$ $F_{.05}(6,26)=2.47$

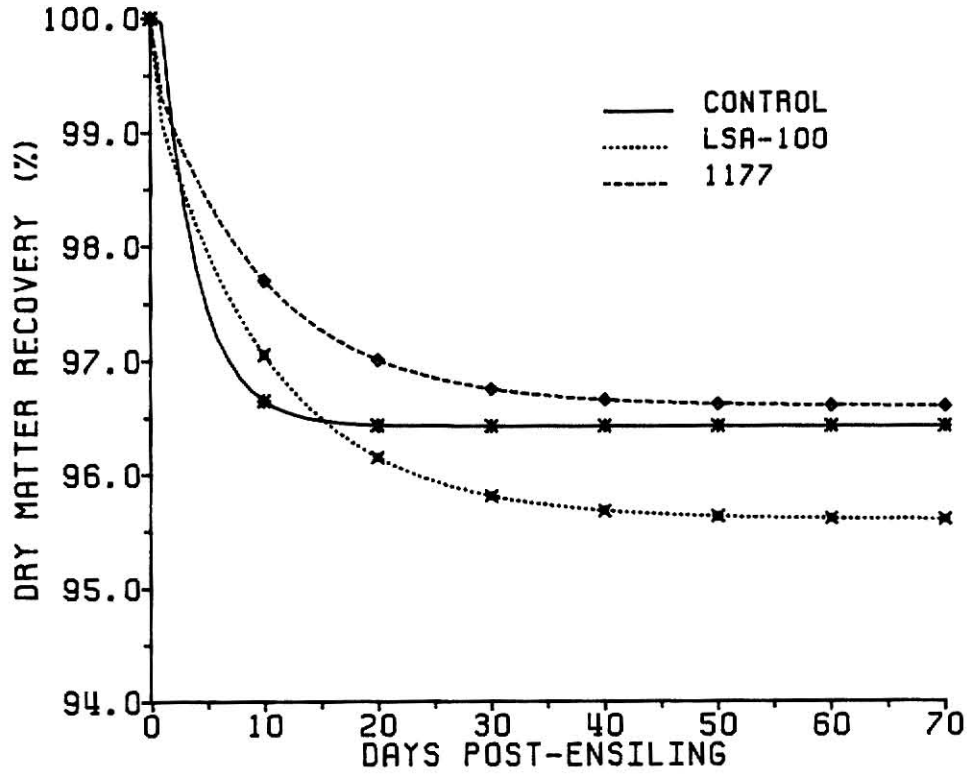


APPENDIX FIGURE 7. Model response curves for pH dynamics (0-70 d), trial 1.

APPENDIX TABLE 8. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of dry matter recovery dynamics, trial 3.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	96.60	3.00	.10	70.42	10
LSA-100	95.60	3.83	.10	21.93	10
1177	96.42	4.81	.31	17.56	10
Pooled data	---	---	---	109.92	30
Combined data	96.53	3.38	.22	122.94	36
Difference	---	---	---	13.03	6

$F=(13.03/6)/(109.92/30)= .593$ $F_{.05}(6,30)=2.42$

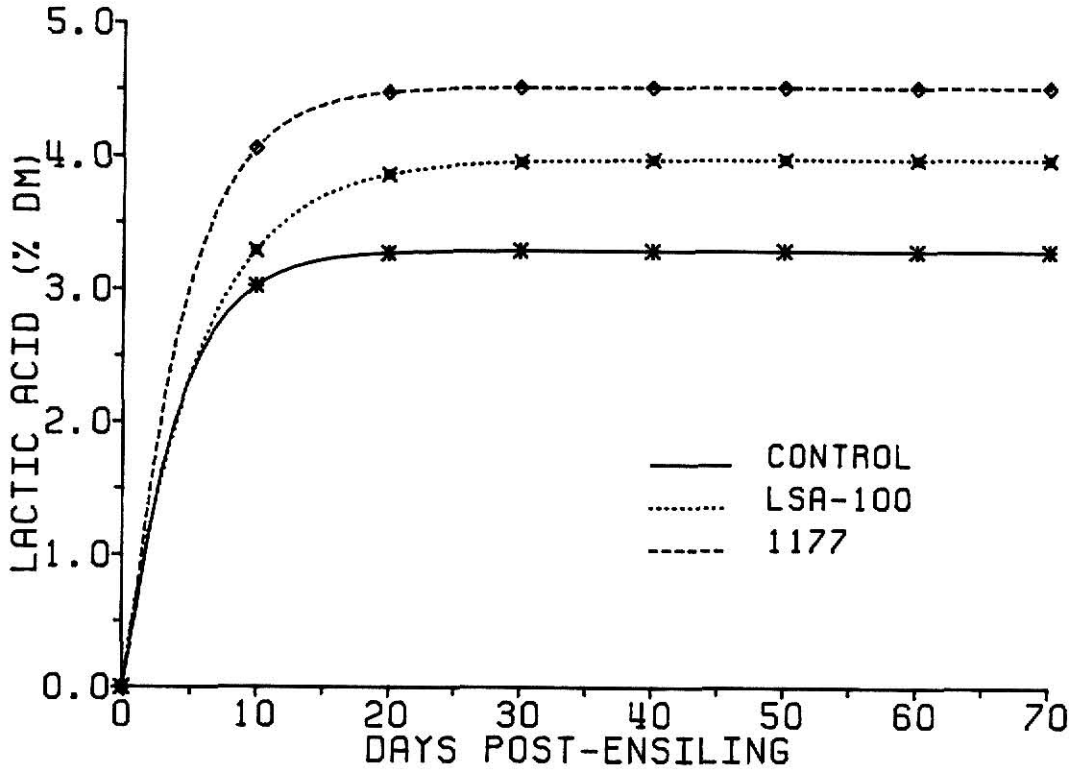


APPENDIX FIGURE 8. Model response curves for dry matter recovery dynamics (0-70 d), trial 3.

APPENDIX TABLE 9. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of lactic acid dynamics, trial 3.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	.050	-.0044	.24	.00021	12
LSA-100	.040	-.0001	.17	.00084	12
1177	.036	-.0027	.26	.00011	12
Pooled data	---	---	---	.00116	36
Combined data	.042	-.0028	.23	.00180	42
Difference	---	---	---	.00064	6

$F=(.00064/6)/(.00116/36)=3.326$ $F_{.05}(6,36)=2.36$

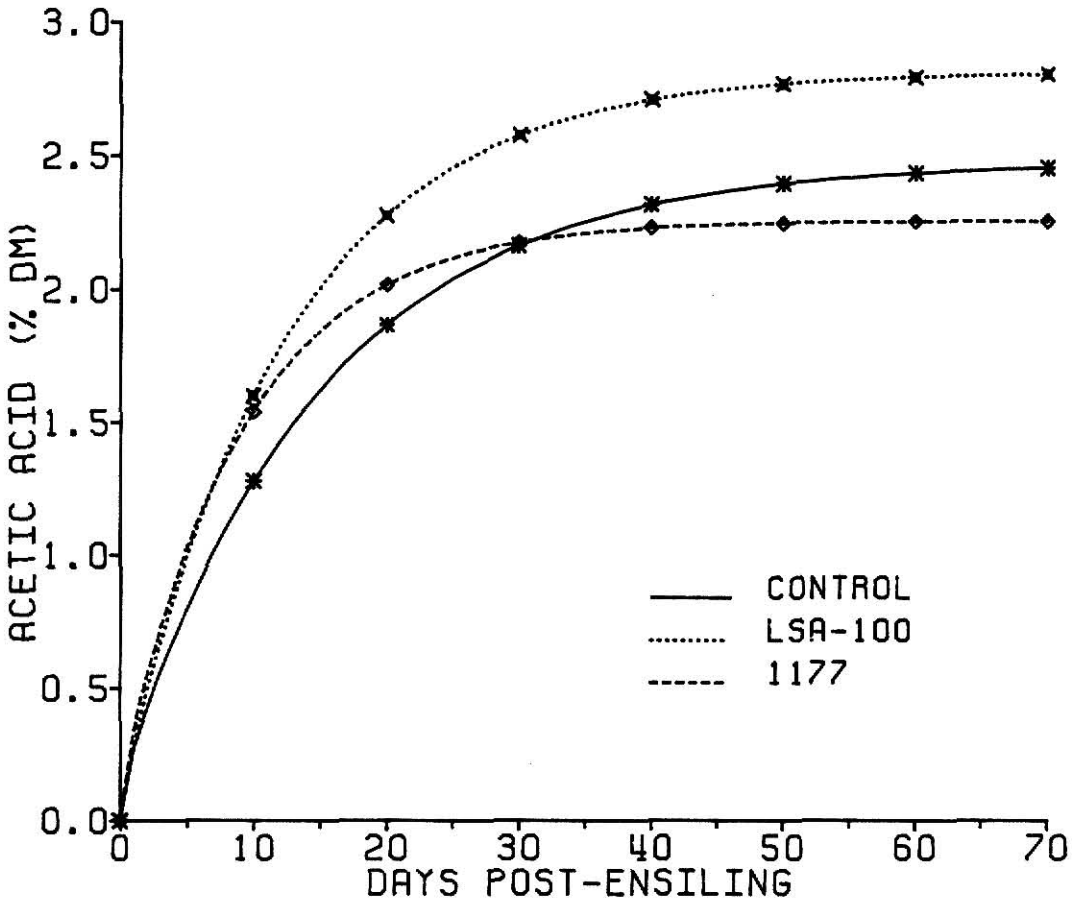


APPENDIX FIGURE 9. Model response curves for lactic acid dynamics (0-70 d), trial 3.

APPENDIX TABLE 10. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of acetic acid dynamics, trial 3.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	.021	.0013	.11	.00022	12
LSA-100	.027	.0008	.08	.00004	12
1177	.024	.0013	.07	.00028	12
Pooled data	---	---	---	.00054	36
Combined data	.024	.0012	.08	.00065	42
Difference	---	---	---	.00011	6

$F=(.00011/6)/(.00054/36)=1.222$ $F_{.05}(6,36)=2.36$

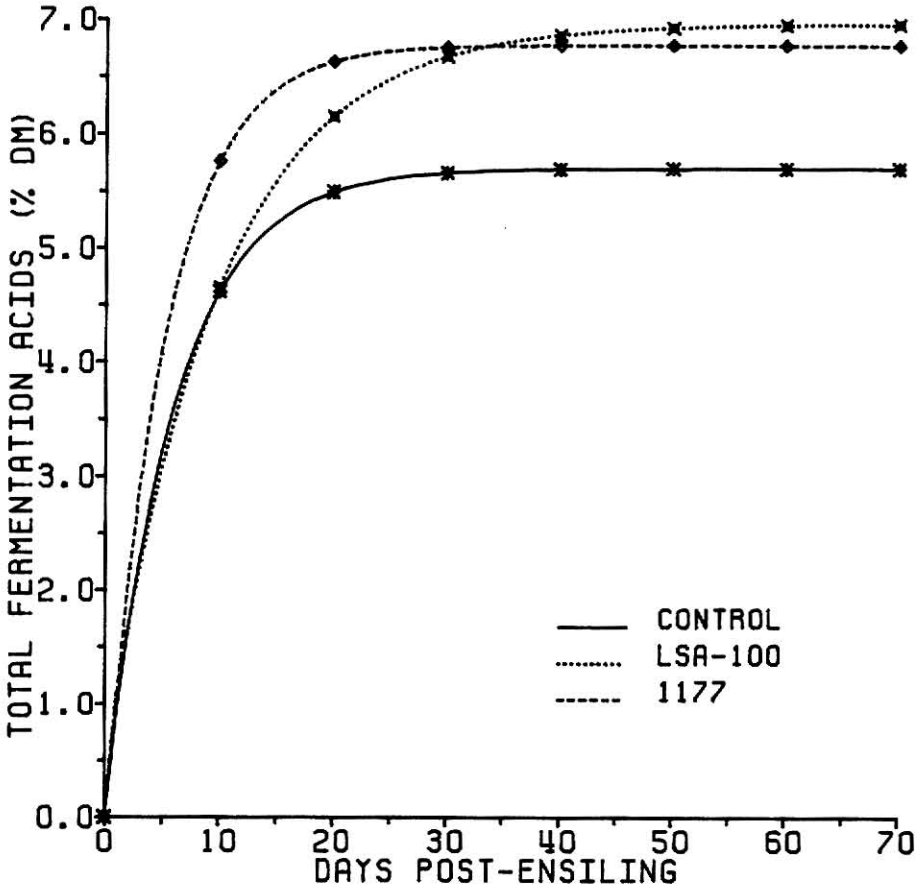


APPENDIX FIGURE 10. Model response curves for acetic acid dynamics (0-70 d), trial 3.

APPENDIX TABLE 11. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of total fermentation acids dynamics, trial 3.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	.070	-.0020	.19	.00062	12
LSA-100	.065	.0044	.10	.00099	12
1177	.057	.0004	.17	.00021	12
Pooled data	---	---	---	.00182	36
Combined data	.064	.0007	.15	.00262	42
Difference	---	---	---	.00080	6

$F=(.00080/6)/(.00182/36)=2.649$ $F_{.05}(6,36)=2.36$

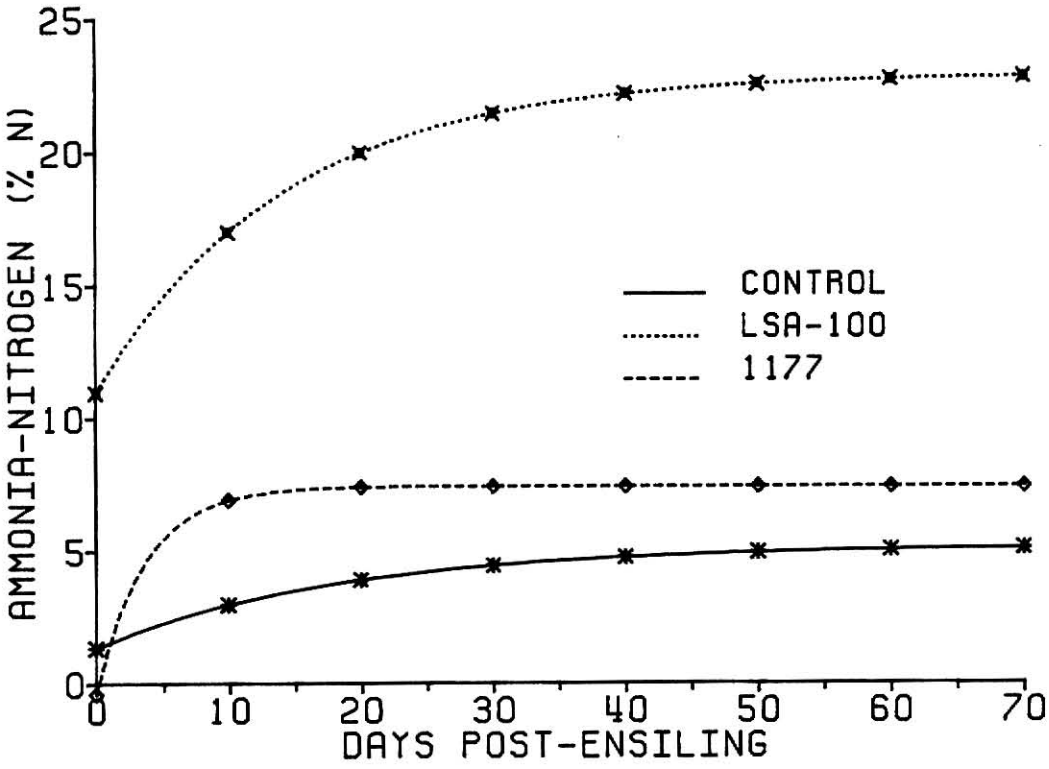


APPENDIX FIGURE 11. Model response curves for total fermentation acids dynamics (0-70 d), trial 3.

APPENDIX TABLE 12. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of ammonia-nitrogen dynamics, trial 3.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	-.0004	.0783	.27	.0199	11
LSA-100	.1097	.1195	.07	.0042	11
1177	.0134	.0384	.06	.0009	11
Pooled data	---	---	---	.0250	33
Combined data	.0462	.0735	.09	.2093	39
Difference	---	---	---	.1843	6

$F=(.1843/6)/(.0250/33)=40.55$ $F_{.05}(6,33)=2.39$

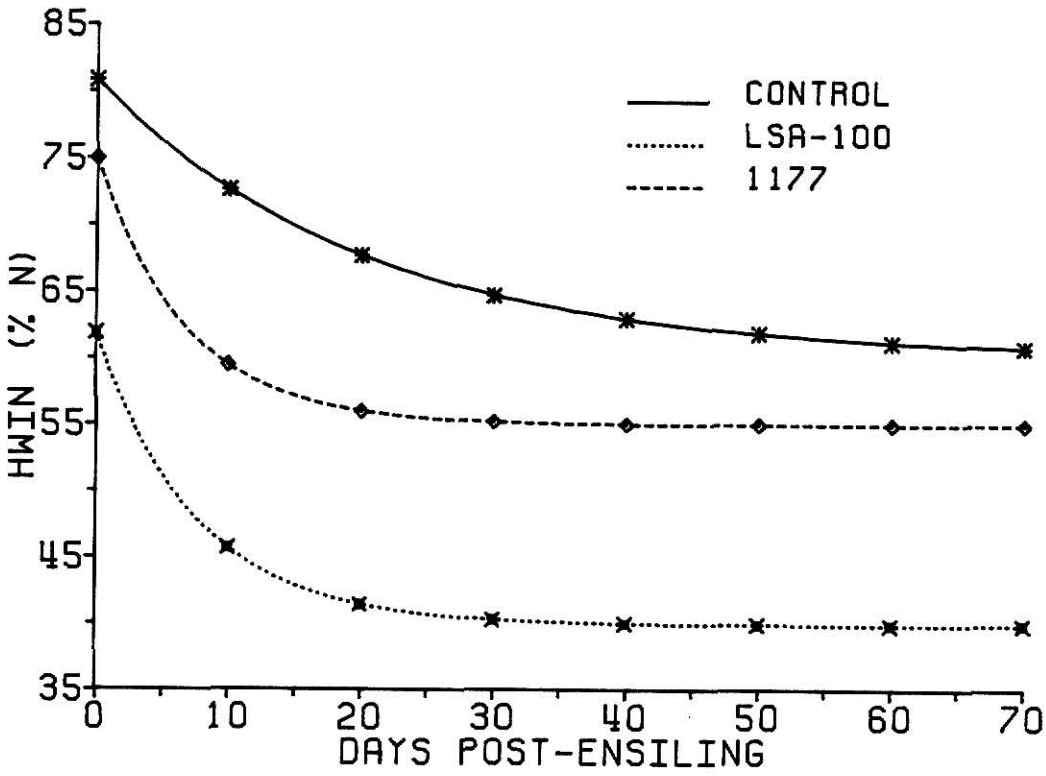


APPENDIX FIGURE 12. Model response curves for ammonia-nitrogen dynamics (0-70 d), trial 3.

APPENDIX TABLE 13. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of hot water insoluble-nitrogen dynamics, trial 3.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	55.00	20.00	.15	4,295	11
LSA-100	39.90	21.98	.13	1,527	11
1177	60.26	20.58	.05	767	11
Pooled data	---	---	---	6,589	33
Combined data	55.00	20.00	.17	10,465	39
Difference	---	---	---	3,876	6

$F=(3,876/6)/(6,589/33)=3.235$ $F_{.05}(6,33)=2.39$

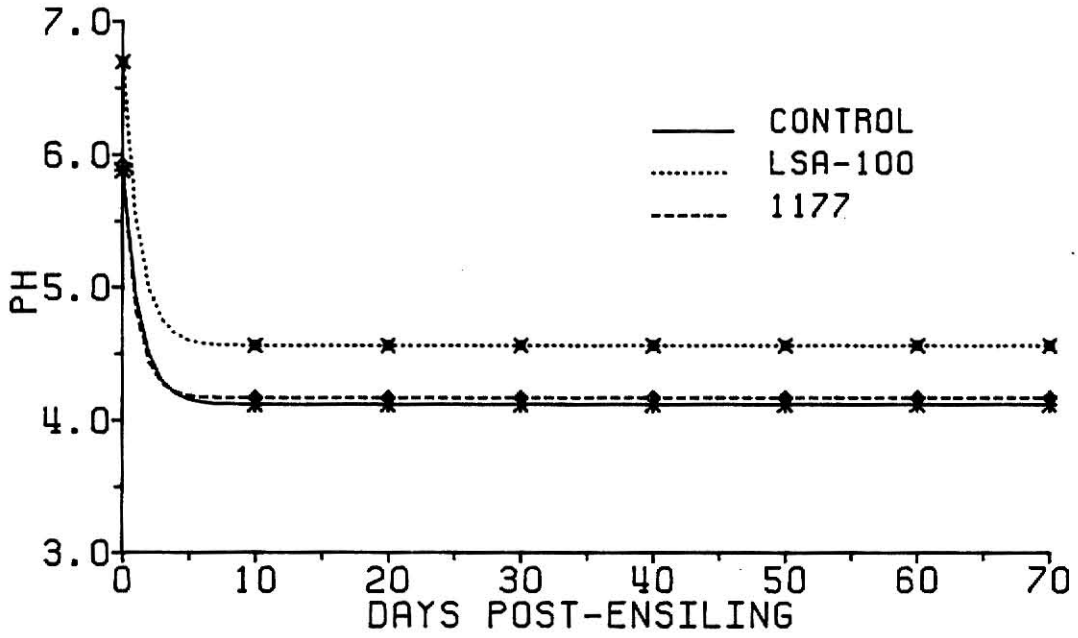


APPENDIX FIGURE 13. Model response curves for hot water insoluble-nitrogen dynamics (HWIN, 0-70 d), trial 3.

APPENDIX TABLE 14. Parameter estimates, residual sum of squares, and degrees of freedom needed for the model comparison of pH dynamics, trial 3.

Silage Treatment	Parameter estimates A	B	C	Residual sum of squares	Degrees of freedom
Control	4.170	4.441	.93	.248	11
LSA-100	4.564	4.729	.80	.047	11
1177	4.119	3.771	.76	.013	11
Pooled data	---	---	---	.308	33
Combined data	4.284	4.278	.82	2.933	39
Difference	---	---	---	2.625	6

$F=(2.625/6)/(.308/33)=46.875$ $F_{.05}(6,33)=2.39$



APPENDIX FIGURE 14. Model response curves for pH dynamics (0-70 d), trial 3.

EFFECTS OF NON-PROTEIN NITROGEN, LACTOBACILLUS INOCULANT, AND SILO TYPE ON FERMENTATION AND NUTRITIVE VALUE OF FORAGE SORGHUM SILAGES

by

MARK ALAN HINDS

B. S., University of Illinois, 1980

AN ABSTRACT OF A MASTER THESIS

Submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1983

ABSTRACT

The objectives of this investigation were to evaluate a urea-molasses-mineral solution (NPN) and a lactobacillus inoculant (Inoc) on the rate and extent of fermentation, aerobic stability, and feeding value of forage sorghum for cattle and lambs; and to compare farm-scale stave silos (CSS) with experimental silos, 20 l containers (Con) and buried nylon bags (Bag). Forage sorghum was ensiled in CSS, Con, and Bag in three trials and treatments were: 1) control, no additive (C); 2) NPN, 1.7% of fresh crop; and 3) Inoc, .05% of fresh crop. Inoc and nylon bag treatments were not included in trial 2.

Forage in experimental silos underwent a more ($P<.05$) extensive and efficient fermentation than forage in CSS as indicated by lower pH values, higher total fermentation acids (TFA), and higher dry matter recoveries (DMR). NPN silage had higher ($P<.05$) ammonia-nitrogen, pH, acetic and TFA when compared with C. Inoc had higher ($P<.05$) DMR and lactic:acetic acid than C, indicating a more homofermentative fermentation. Silage fermentation dynamics were evaluated in Con silos with sampling on days 1, 2, 3, 4, 12, and 122 post-ensiling in trial 1 and 1, 2, 4, 12, and 70 in trial 3. Dynamics were affected by initial dry matter content and NPN and Inoc additions. In trial 3, Inoc and NPN increased ($P<.05$)(10 to 70 d and 26 to 70 d, respectively) TFA over C; Inoc by increasing lactic acid and NPN by increasing all fermentation acids.

One hundred eleven steers were fed in three growing trials as an incomplete block design to compare the three silage diets: C plus a soybean meal (SBM) supplement (C+SBM); NPN plus a grain sorghum (milo) supplement (NPN+milo); and Inoc plus SBM (Inoc+SBM). In trials 1 and 2, steers were fed silage ad libitum plus .68 and 1.01 kg of supplement, respectively, once daily while in trial 3 steers were fed similar to trial 2 but twice daily.

NPN silage resulted in higher feed intake, faster daily gains, and similar feed conversion when compared with C or Inoc silages.

The silages in trial 1 were evaluated using 25 wether lambs in a digestion trial with diets that were 85% silage and 15% appropriate supplement fed once daily. Silages and supplements compared were: C+SBM, NPN+milo, Inoc+SBM, C plus urea supplement (C+urea), and C plus NPN supplement (C+NPN). The NPN supplement was the same solution that was applied to the NPN silage at the time of ensiling. The five diets had similar feed intakes but the NPN-milo diet had a higher ($P<.05$) dry matter digestibility than the C+urea diet. Nitrogen retention was highest for the Inoc+SBM and C+NPN diets; lowest, for the C+urea diet.