YIELD, COMPOSITION, AND NUTRITIVE VALUE OF WHOLE-PLANT GRAIN SORGHUM SILAGE: EFFECTS OF HYBRID, MATURITY, AND GRAIN ADDITION

by

BRETT HOWARD KIRCH

B. S., University of Nebraska-Lincoln, 1984

A MASTER'S 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

1989

Approved by:

Major Professor

Acknowledgements

I would like to first and foremost thank my parents and the rest of my family, whose love, guidance, and support has made this achievement possible.

Special recognition to Dr. Keith Bolsen, major professor, for his patience and guidance throughout the course of my graduate studies. Thanks also to Drs. L. Harbers and J. Riley for their help and for serving on my graduate committee.

Many thanks to my special friends, Jim and Kristin White, Pete and Susan Hamma, and Seyed Azimi and family for their kindness and friendship during my graduate studies. And a special thanks to my friend and roommate Allan Fritz, who endured much of my wrath.

Appreciation also to Ted Walter, Agronomy; Jim Hoover, Farm Shop; Ron Pope, Beef Research; John Scheele and Harvey Ilg, Sheep Research; Lesa Nuzback, Nutrition Lab; and their crews for their technical assistance.

Special recognition is due to Kristin White for typing this manuscript and Annette Hoover for the many hours of calculations in summarizing the data. Their patience and dedication are very much appreciated.

I would like to dedicate this manuscript in memory of my late grandmother, Naomi B. Kirkpatrick, whose love and encouragement have been inspirational in my life.

Table of Contents

List of Tables

List of Figures

List of Appendix Tables

Introduction

The primary whole-plant silage for the beef cattle industry in the Great Plains region of the United States has been corn (Zea mays L.). Limited water resources and higher production costs have forced a search for alternative crops. As a result, the number of acres committed to sorghum (Sorghum bicolor L. Moench) has increased dramatically over the past few years.

Forage sorghums, which are predominately used for silage, are more drought tolerant than corn, but often produce silages which are lower in dry matter content and support low rates of gain when fed to growing cattle (Fox et al. 1970 and McCullough et al. 1981). Conclusions from research by Brethour (1967) stated that the lower cattle performance from forage sorghum silages was due to their low grain content. As a result, there is increasing interest in the use of "combine-type" grain sorghum as a whole-plant silage crop. Grain sorghums have similar drought-tolerance as forage sorghums, but usually contain more grain, which leads to faster rates of gain. Research by Smith (1986) and Hamma (1987) showed that grain sorghums produced silages which were higher in dry matter and required less supplemental protein in growing cattle diets. The faster gain from and the higher crude protein content of grain sorghums largely offset any yield advantage shown by forage sorghums.

With grain content being a major determinate of nutritive value, increasing the grain proportion in silages should produce superior performance in backgrounding cattle. Research by Brethour and

Duitsman (1966) and Smith et al. (1966) showed that adding grain to forage sorghum silages improved rates of gain. McCullough et al. (1981), however, demonstrated that large grain additions to forage sorghum silages actually depressed cattle gains. That raises the question of whether grain addition to grain sorghum silages would be beneficial in growing cattle diets.

Two experiments were conducted to compare the nutritive value of whole-plant silages from several grain sorghum hybrids, and to study the effect of adding grain to whole-plant sorghum silage diets on performance of growing cattle. Effects of grain sorghum hybrid and stage of maturity at harvest on agronomic and nutritive characteristics were further documented in a third experiment. Whole-plant forage sorghum and/or corn hybrids were included for comparative purposes in all experiments.

Chapter I

REVIEW OF LITERATURE

A. The Effect of Maturity upon Yield, Composition, and Nutritive Value of Sorghum

The maturation of the sorghum plant is highly complex, varying not only between cultivars, but within cultivars and environments. In an attempt to standardize and characterize sorghum development, Vanderlip and Reeves (1972) categorized the growth of sorghum into 10 stages shown in Table 1.

1. Forage sorghum.

Black et al. (1980) harvested forage sorghum (DeKalb FS-24) at six stages of maturity: early-bloom, bloom, milk, late-milk, early dough, dough, and hard grain. The resulting silages showed a decline in crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) as the maturity advanced. At the same time, neutral detergent solubles increased with maturity. Plant part determinations showed that stalks comprised the greatest proportion of the plant at all stages. Percentage of heads increased from 5% at early-bloom to 36% at the hard-dough stage, while the percentage of leaves decreased with maturity from 31 to 18 percent. Gross and digestible energy yields (Mcal/ha) were highest at the late-milk to early-dough stages and declined sharply in later harvests. The digestibilities of all other nutritional components were depressed with advancing maturity.

TABLE 1. IDENTIFYING CHARACTERISTICS OF THE GROWTH STAGES OF SORGHUM[1]

Growth stage	Identifying characteristics
0	Emergence. Coleoptile visible at soil surface.
1	Collar of 3rd leaf visible.
2	Collar of 5th leaf visible.
3	Growing point differentiation. Approximately 8th leaf stage by previous criteria.
4	Final leaf visible in whorl.
5	Boot. Head extended into flag leaf sheath.
6	Half-bloom. Half of the plants at some stage of bloom.
7	Soft-dough.
8	Hard-dough.
9	Physiological maturity. Maximum dry matter accumulation.

[1] From Vanderlip and Reeves (1972).

Cummins (1981) harvested four forage sorghums (DeKalb FS-16, Funk's 2625, Pioneer 927, and DeKalb 25-E) at four stages of maturity: late-milk, early-dough, dough, and hard dough. Dry matter (DM) accumulated in all four hybrids as maturity increased. The plant parts analysis showed the percentage of DM increased in the heads with advancing maturity, while percentage of DM in the leaves and stalks decreased. The hybrids also differed in component distribution which caused those with higher stalk content to not accumulate DM as fast as the other hybrids. In vitro dry matter digestibility (IVDMD) percentage reached a maximum at the early-dough stage for both heads and leaves, while the IVDMD of the stalks varied only slightly with maturity. The percentage of ADF in the leaves increased with maturity while the ADF percentage in the stalk showed little change.

Owen (1962) harvested Atlas sorghum at milk, soft dough, hard-dough, and mature grain stages. Advancing maturity produced increases in DM and nitrogen free extract (NFE) and decreases in CP, crude fiber (CF), and ether extract (EE). Green fodder yields increased from early-milk to the mature-grain stage. When the resulting silages were fed to lactating dairy cows, dry matter intake (DMI) increased while 4% fat-corrected milk (FCM) per pound of DMI decreased. Milk fat percentage and body weight change were not significantly affected by maturity at harvest. The author concluded that since performance of lactating cows was not significantly affected by maturity at harvest, Atlas sorghum should be harvested to maximize yield.

In the second study by Owen and Kuhlman (1967), two forage sorghums, Atlas and Rox, were harvested at three stages of maturity:

milk, medium-dough, and hard-dough. The resulting silages were fed to Holstein heifers, and digestibilities were determined using the Cr_2O_3 marker technique. The DM digestibility of Atlas was depressed from 55% to 46% by advancing maturity from milk to hard-dough stage, Energy and CP digestibilities were also depressed by advancing maturity at harvest. Rox silage did not show any significant changes as a result of advancing maturity.

Dotzenko (1965) harvested seven sorghum varieties (six forage sorghums and one grain sorghum) plus one corn variety at six stages of maturity ranging from panicle emergence to hard-dough stages. All entries showed an increase in DM accumulation and a decrease in total nitrogen as maturity advanced. All silages were well preserved, but the pH of the silages increased with maturity for all varieties. Hand refractometer readings of stalk juice showed marked increases in sugar percentages in all varieties from panicle emergence to pollination, but sugar content declined with further advances in maturity.

Three forage sorghum hybrids (Pioneer 947, Acco 351, and DeKalb FS-25-E) were harvested at four maturities (late-milk to early-dough, late-dough, post-freeze hard-grain, and two to four weeks post hard grain) by Hamma (1987). The resulting silages were then fed to sheep in digestion studies. The silages showed a DM content increase and CP decrease with advancing maturity. The highest DM yields were either at the late-milk or late-dough stages. Intake of the silages increased with advancing maturity for two of the three hybrids. Dry matter digestibility was not affected by maturity in any of the three hybrids.

Danley and Vetter (1973) used two varieties of forage sorghum and two corn varieties to study the effects of advancing maturity on the carbohydrate and nitrogen fractions and *in vitro* digestibility. As maturity increased, an increase in DM and hemicellulose was observed, while CP and total digestible nutrients (TDN) decreased. Water soluble nitrogen or soluble non-protein nitrogen content were not effected by maturity. The lignin content also increased with maturity and was highly correlated with the decrease in digestibility.

2. Grain sorghum.

Johnson et al. (1971) used bird-resistant grain sorghums to study the effect of maturity on the chemical composition and digestibility of the resulting silages. The accumulation of DM was greatest in the leaves and heads as maturity increased, while DM content in the stalks remained constant. At the hard-grain stage the head constituted 55% of the total plant DM, while the stalk had dropped to 15 percent. Protein and cellulose percentages declined with maturity of the whole-plant; while NDF, ADF, and lignin percentages increased. Soluble carbohydrates declined rapidly in all components as plant maturity advanced. Protein and cellulose digestibilities declined with maturity. However, protein digestibility did increase after frost, but intake and DM digestibility were not affected by maturity.

In a two year study, Browning and Lusk (1967) determined the relative feeding value of grain sorghum (RS 610) harvested at three stages of maturity. A decrease in CF and an increase in NFE were noted as maturity advanced. Dry matter yield increased by .29 metric tons/ha and by .55 metric tons/ha in year one and two respectively, as maturity progressed from stage one to stage three. During the same time, the sorghum heads increased from 36 to 67% DM and the DM represented by grain doubled in the whole-crop. In the lactation studies using these silages, DM intake increased with each stage of maturity; however, there were no differences in average daily FCM production or milk fat percentage in either year. Crude protein digestibility decreased significantly with advancing maturity, and a trend toward lower DM, EE, and gross energy digestibilities.

Smith (1986) harvested six grain sorghums and one forage sorghum at three stages: early-dough, late-dough, and hard-grain. Highest whole-plant DM and grain yields occurred at the late-dough stage for the grain sorghums. Although DM yield for the forage sorghum decreased, grain yield increased as maturity advanced. Grain to forage ratios increased with maturity in both sorghum types. Grain sorghum silage increased in DM content and decreased in CP content as maturity advanced. The forage sorghum showed only a slight change in DM content and no change in CP content as maturity advanced. Silage fermentation was less extensive in the drier, more mature silages.

B. Nutritional Value Comparisons of Corn and Sorghum Silages

Whole-crop corn silage is generally regarded as the beef industry's most important silage crop, and corn silage is considered to be superior nutritionally to both forage and grain sorghum silages. However, sorghums tend to be better suited for drier climates, such as the Great Plains, and for systems where double cropping can be utilized. So in these areas, the choice of a sorghum cultivar is an important decision for beef and dairy cattle producers.

1. Forage sorghum vs corn.

In work by Cummins and McCullough (1969) heifers were fed silages from three corn and forage sorghum hybrids. Each of the hybrids used was selected to represent a variation in genetic potential. Intake results showed corn silage DM was consumed in greater amounts than forage sorghum DM (10.8 vs 8.7 lbs/day). *In vitro* whole-plant DM digestibilities from four experiments averaged 7% more for corn silages than for sorghum silages.

Brethour (1967) compared corn silage with forage sorghum for wintering steer calves. Corn silage supported 23% higher gains than the forage sorghum silage (.98 vs .72 kg/day), while intake (6.1 vs 5.9 kg/day) and efficiency of gain (6.2 vs 7.8 kg of DM/ kg of gain) tended to be better for corn silage.

Nordquist and Rumery (1967) compared corn silage with three forage sorghum silages both agronomically and as feed for lactating dairy cattle. Dry matter yields were highest for the forage sorghums, while grain production was highest for the corn. Crude protein content was highest in the corn, while CF was highest in the sorghum silages. Ether extract and ash showed no significant differences between any of the silages. In two years of feeding lactating cows, corn silage produced significantly more milk than the sorghum silages, however, milk fat and solids were not different. Changes in body weight were not significant between cattle fed corn or sorghum silages. The conclusions of the authors were that while yields of forage sorghum silages were greater, their nutritional values were somewhat lower than corn silages.

Owen et al. (1957) compared corn silage (Dixie 18) to three sorghum silages (Sart, Tracy, and Texas seeded-ribbon). The silages were fed to lactating dairy cattle over a three year period. In each of the trials, the differences in silage consumption, production of 4% FCM, and change in body weight were highly significant in favor of corn silage over each cultivar of sorghum silage. Sart and Tracy sorghums supported similar milk production; however, Tracy silage was superior to Texas seeded-ribbon in milk production and changes in body weight. Milk produced by cows receiving Tracy sorghum did not have a stronger silage flavor when tested by flavor score.

In a two-year study, Lance et al. (1964) compared hybrid corn silage with forage sorghum silage for lactating dairy cattle. Both years, cows fed corn silage produced significantly more FCM and consumed more DM than those fed sorghum silage. As a result, sorghum silage was determined to be 92 and 85% as efficient as corn silage for milk production. In year 1, the cows consuming forage sorghum silage had significantly more body weight gain than those fed corn silage.

In year 2, however, these differences were not significant. Digestion trial results showed digestion coefficients for DM and energy were significantly greater for corn silage in year 2. In year 1, there were no significant differences in digestibilities among the silages.

2. Grain sorghum vs corn.

Browning et al. (1961) compared corn (Dixie 55) harvested in the early-dent stage to two grain sorghums (RS 610 and NK 300, intermediate forage type grain sorghum) harvested in the milk to early-dough stage using lactating cows. Silage consumption per 100 lbs. body weight for the corn, NK 300, and RS 610 was 1.22, 1.38, and 2.24 lbs., respectively. Average daily FCM was significantly higher for the RS 610 (32.1 lbs.) when compared to corn (25.9 lbs.) and NK 300 (25.7 lbs.).

In a later study, Browning and Lusk (1966) compared Dixie 55 corn, RS 610 grain sorghum, and Hegari forage sorghum in digestion and lactation trials. Average daily FCM production was not affected by type of silage; however, the grain sorghum silage did have a significantly higher DM intake and a higher milk fat percent. In the digestion trial with bred dairy heifers, DM intake was significantly higher for the grain sorghum silage, when compared to the other two silages. Digestion coefficients for DM, cellulose, and gross energy were greatest for the corn silage. Crude protein digestibilities were similar for the corn and grain sorghum and both were higher than the forage sorghum. Three other unpublished lactation studies (as cited by Browning and Lusk, 1966) comparing grain sorghum with corn silage showed significant differences in silage DM intake in favor of grain sorghum. Milk production and milk fat percent showed little difference among the silages.

Contrary to the previous studies, other researchers have determined corn silage to be superior to grain sorghum silage. Brethour and Duitsman (1966a) compared grain sorghum silages with corn silages and reported that steer calves fed corn silage gained significantly faster and more efficiently than calves fed grain sorghum silage.

Fox et al. (1970) compared corn silage with bird-resistant grain sorghum (BRGS) silage. Both crops were ensiled at a mature stage of grain development and were fed to Hereford steer calves in a long-term finishing trial. Steers fed corn silage produced faster gains (1.00 vs .73 kg/day), consumed less DM (5.9 vs 6.9 kg/day), and were more efficient (5.9 vs 9.4 kg of feed/kg gain) than those fed BRGS silage. In conjunction with the feeding trial, a digestion trail using yearling steers was conducted to help explain the performance results. Besides the two previous silages, an immature stage (milk to soft-dough) BRGS was included. Corn silage was significantly higher in apparent digestibilities of DM, cellulose, and protein when compared to the mature BRGS. THe immature BRGS was shown to be intermediate in digestibility. Separation of grain and stover in feed and feces also showed that the lower digestibility of the mature BRGS silage was due to lower digestibilities of both grain (22%) and stover (16%) portions.

In a 112 day feedlot study, Coombs and Nipper (1984) fed corn and grain sorghum silages supplemented with urea. Cattle consuming corn silage had slightly higher average daily gains (2.4 vs 2.2 lbs.), DM intakes (15.2 vs 15.0 lbs./day) and the more efficient gain (6.2 vs 6.7 lbs. of DM/lb. of gain).

Bolsen (unpublished data) and Bolsen et al. (1983) also found grain sorghum to be inferior nutritionally to corn silage. In trial one, yearling steers were used to compare grain sorghum silage (44% DM) and corn silage (36% DM). Results of the first trial showed that DM intake of the grain sorghum silage was slightly higher than the intake of corn silage. However, average daily gain and feed efficiency favored the corn silage. In the second trial, Ferry-Morse 81 grain sorghum (37% DM) and Ferry-Morse 3020 corn (54.4% DM) were compared using steer and heifer calves. Corn silage produced significantly faster gains and higher intakes than the grain sorghum silage. Feed efficiency, while not significantly different, also favored the corn silage.

C. Agronomic and Animal Performance Characteristics of Sorghum Silage Cultivars

Large differences in grain production are often reported for sorghums. Sorghum types range from the male-sterile forage sorghum hybrids, which produce no grain, to the high grain producing combine-type grain sorghums.

Owen et al. (1962) evaluated two sterile forage sorghum hybrids (RS 303F and RS 301F) and corn as silages for lactating cows. When RS303F, Axtell sorgo, and corn were compared in the first trial, corn silage produced the most FCM, while DM intake was highest for the Axtell sorgo. RS 303F and Axtell sorgo silages were found to be similar in other aspects. In the second trial, silages were harvested at early-dough and mature-grain from RS301F and Tracy forage sorghum were compared. RS 301F silage was significantly superior to Tracy in FCM production and milk fat percent when harvested at early-dough stage, but these values were not significantly different for silages from 303F and mature Tracy forage sorghum.

Boren et al. (1962) compared silages made from the sterile and fertile parent of FS 210 hybrid forage sorghum. Silage produced from the fertile parent was superior to the sterile parent silage for average daily gain, DM intake, and feed efficiency in beef cattle. In agronomic comparisons, the fertile parent was superior to the sterile parent silage for average daily gain, DM intake, and feed efficiency in beef cattle. In agronomic comparisons, the fertile parent was superior to the sterile in DM yields/hectare. Ritchie et al. (1972) compared silage Pioneer 931 (tall, late-maturing, male sterile hybrid) to silage from NK 300 (short, early-maturing, high-grain producing hybrid) in a cattle feeding trial. Bred heifers consuming NK 300 silage had significantly faster gains and higher intakes than those fed Pioneer 931 silage; however, DM yields/ha were greater from Pioneer 931.

Pioneer 931 and DeKalb FS4 were compared by Brethour (1977, 1978). In the first year, DM intake was highest for the drier (23 vs 30% DM) DeKalb FS4 silage, but average daily gain for steers was not different. In the second year, Pioneer 931 was delayed in harvest to increase its DM content and prevent effluent production in the silo. Steer performance, however was substantially lower for Pioneer 931 in the second year.

Bolsen et al. (1983) compared three sorghum types: non-heading forage sorghum (Funk's G-1990); forage sorghum (Pioneer 947); and a grain sorghum (DeKalb E67). Based on rates and efficiencies of gain (beef calves) relative feeding values for the three silages were 62, 94, and 100 respectively. Pioneer 947 and DeKalb E67 produced similar silage DM yields/ha, while the non-heading hybrid produced the lowest yield. Later results by Smith et al. (1985) gave similar results. Funk's G-1990 non-heading sorghum, DeKalb FS-25A+ forage sorghum, and DeKalb 42Y grain sorghum silages were evaluated using growing steers, and based on rates and efficiencies of gain, relative feeding values for the three sorghum silages were 67, 75, and 100, respectively.

A non-heading forage sorghum (Funk's G-1990) was compared with a grain producing forage sorghum (Cargill 200F) in sheep digestion trials (Smith et al., 1984). Both hybrids were harvested pre- and post-freeze and DM digestibilities were lowest for the non-heading silages. Post-freeze silages had lower CF digestibilities regardless of sorghum type. In a study by Hamma (1987), Acco 351, a high to moderate grain-containing forage sorghum, Pioneer 947, a moderate grain-containing forage sorghum, and DeKalb 25-E, a low grain-containing forage sorghum were compared in sheep digestion and cattle feeding trials to determine digestibilities and voluntary intakes, Acco 351 (high-grain) silage was consumed in significantly higher amounts than the other two hybrids. DeKalb 25-E (low-grain) produced the lowest intake. Digestibilities of DM, NDF, and ADF were similar for all three hybrids; however, DeKalb 25-E did have the highest CP digestibility. In the feeding trial, Buffalo Canex, a moderate to high grain containing forage sorghum, and DeKalb 42Y, a grain sorghum, were also included. DeKalb 42Y silage supported the highest average daily gain and DM intake, while DeKalb 25-E produced the lowest gain and intake. The other three hybrids gave similar daily gains and DM intakes. Calves fed 42Y, 947, 351, and Canex had similar feed efficiencies.

Rupp et al. (1975) compared digestibilities of ORA-T grain sorghum and FS-1a forage sorghum silages using Holstein heifers. Silages from ORA-T and FS-1a had apparent digestion coefficients of 74 and 65% for whole-crop DM; 74 and 66% for energy; and 66 and 55% for stover DM. The digestible energy values were 2.75 and 3.08 Kcal/g of DM for FS-1a and ORA-T respectively.

Johnson et al. (1971) determined that there were no significant differences in chemical composition or apparent digestibility among silages produced from four cultivars of BRGS. Contrary to these results, Pund (1970) found bird-resistant grain sorghums to be inferior silages compared to non-bird-resistant cultivars. Bird-resistant grain sorghum silage produced significantly lower gains for steers and 17.2% more DM was required per kg of gain. Silage DM yield/ha was also lower for the bird-resistant cultivar.

Five forage sorghum cultivars (Beefbuilder, Tracy, L 115F, Milkmaker, and NK 320) were evaluated by Owen and Furr (1967). Cultivars accounted for significant variations in nitrogen, calcium, phosphorous, sulfur, zinc, and manganese percentages. Beefbuilder produced the highest DM yield/ha, while L 115F was the second highest.

Multiple hybrid comparisons of both yield and silage quality in any one experiment are seldom reported in the literature. Cummins et al. (1970) evaluated 25 sorghum cultivars over three years and two locations, with 12 cultivars being common to all three years. Cultivars were categorized on the basis of height: short, up to 6 feet tall; medium, 6 to 9 feet; and tall, over 9 feet. Direct correlations between plant height and DM yield were found. At one location, across three years, the percentage of plant dry weight in the heads ranged from 11 to 35%; in the leaves, from 14 to 22%; and in the stalks, from 43 to 71 percent. At location two, across two years, the average ranged from 26 to 56% for heads; 10 to 15% for leaves; and 30 to 59% for stalks. Whole-plant in vitro DM digestibilities ranged from 40 to 52% from two years of data at one location.

Schmid et al. (1976) reported correlations between agronomic and quality traits for 14 sorghum cultivars. Wide variations in genotypic backgrounds were contained in this study, which included a sudan grass, a grain sorghum, several sweet sorghums, and a sorgo-sudan hybrid. Several cultivars were grown in each of the three seasons, but some were grown only one season. Plant height and DM content ranged from 117 to 308 cm and 23.3 to 38.1% respectively. The grain type sorghum silage NK 133) produced the highest average daily gains and DM intakes in sheep. Linear regression analysis of gains and digestible DM intakes (DDMI) showed that low gains from sorghum silages (in comparison to corn silage) were due to DDMI differences. Agronomically, percent stems and heads were most highly correlated with quality traits. Quality traits and plant heights were negatively correlated.

D. Effect of Grain Content on the Nutritional Value of Silage

The importance of grain content on the nutritive value of silage is well documented. Brethour (1967) concluded that the higher the grain content the better the performance by calves fed sorghum silages. White et al. (1988) using five forage sorghums in IVDMD studies, determined the proportion of grain in a forage sorghum silage to be the most influential factor in IVDMD dynamics. The author concluded that grain yield rather than leaf yield was the most appropriate criterion when selecting for increased IVDMD of the silage. As a result many ways of increasing grain content are possible from harvesting to direct addition.

1. Head-chop silage.

Newland et al. (1964) harvested only the center portion of the corn plant, including the ear. Dry matter yield was 73% of the yield for silage harvested by conventional means, while TDN was 25% higher. When fed to steers, the center-cut silage supported lower gains than conventional corn silage which had a similar amount of corn added.

Playne and Skerman (1964) harvested a sweet sorghum (Saccaline) at differing heights from the bottom of the plant. Crude protein content was increased by 13% when cut at 61 cm and increased by 45% when cut at a 152 cm height. Dry matter yields were 75 and 37%, respectively, of silages cut at conventional heights. The authors concluded that these cutting heights were impractical for improving silage protein content.

Hart (1982) harvested WAC 710 DR grain sorghum at three cutting heights (10.2, 40.6, and 63.5 cm) in the soft dough stage and mature stages in an attempt to increase silage digestibilities. While the proportion of stem decreased, and the grain content increased, silage digestibilities were only slightly improved with increased cutting height. The reductions in yield at higher cuttings were not compensated by the small improvements in digestibility.

In a series of studies, Stallcup and York (1986) compared head-chop silages from several common grain sorghums. They determined that the nutritive value of head-chop did not vary among sorghum hybrids. Diets containing head-chop silages successfully maintained production in Jersey cows producing from 29.3 to 32.5 lbs. of solids corrected milk/day. In digestion trial, digestibilities ranged from 67.1 to 70.1% for DM, 45.7 to 47.7% for CP, and 65.0 to 67.4% for energy. Silages made from the stover left after head-chopping were treated with ammonia and fed to steers. The results showed very poor digestibilities and intakes along with poor silage fermentations. The conclusions of the authors were that stover silages were useful only in maintenance diets, while head-chop silage were capable of giving very good cattle performance.

Comparing head-chop sorghum silage ration to a similar dry ration for lactating dairy cows, Leighton et al. (1969) reported greater milk production, feed costs, and weekly weight changes for cows fed the dry ration than for those fed the head-chop ration. Using lactating cows, Daura (1980) compared three diets: one containing silage from grain sorghum harvested as head-chop; another containing whole-plant silage plus added sorghum grain; and a third containing sorghum grain and alfalfa hay. Gains and milk production were not influenced by diet treatment; however, whole-plant silage did produce milk with significantly higher fat content than head-chop silage. The author concluded that the reduced DM yields per unit of land area for harvesting head-chop only served to favor the ensiling of whole-plant silages.

2. Direct grain addition.

The increased grain content in a silage by harvesting method is of questionable value due to the decrease of DM yields. However, adding grain to silages, pre or post ensiling, does have promise, especially during periods of low grain prices.

Gill et al. (1976) used 612 lb. steers to evaluate feedlot rations containing 14, 30, and 75% corn silage (DM basis). Each diet contained 10% supplement, while the remainder was high moisture corn. Cattle receiving the 75% corn silage ration had slower gains (2.5 vs 3.31 lbs) and were fed 28 days longer than cattle fed either 14% or 30% corn silage (196 vs 168 days, respectively). The diets containing 75% and 30% corn silage did have higher intakes than the 14% corn silage diet (18.51, 18.77, and 17.07 lbs., respectively). Feed efficiencies improved as the level of silage dropped in the diet. Carcass traits also favored cattle consuming the lower levels of silage.

In a series of five experiments, Perry and Beeson (1976) evaluated differing levels of corn grain and silage using both steer calves and yearlings. The amount of corn fed in addition to corn silage and supplement ranged from 2 lbs. per head daily to 85.56% of the total DM in the diet. Cattle fed the highest levels of corn along with limited or no corn silage gained significantly faster than those fed high silage diets in four of the five experiments. In the exception, calves fed either one-third or two-thirds of a full-feed of corn gained as rapidly as those fed a full-feed of corn. The differences from the other experiments were attributed to insufficient protein supplementation. Feed efficiencies generally favored the high grain diets; however, when TDN per unit of gain was calculated, the high silage diets were utilized as efficiently as the high grain diets.

Jesse et al. (1976) fed Hereford steers (227 kg) isonitrogenous diets containing the following corn to corn silage ratios (DM basis): (A) 30:70; (B) 50:50; (C) 70:30; and (D) 80:20. Steers fed the high silage diet had the slowest gains (.90 vs 1.06, 1.13. and 1.11 kg/day for diets A, B, C, and D respectively). Dry matter intake expressed as a percent of body weight was 2.25, 2.48, 2.48, and 2.37% for diets A, B, C, and D respectively. Feed efficiency improved from 7.61 to 6.48 kg of DM/kg of gain as dietary energy level increased. Most carcass traits measured were quite similar; however, cattle fed diet C did produce fatter, higher grading carcasses. The authors concluded that feeding higher than 70% corn grain did not appear to be advantageous.

In experiments conducted by Woody et al. (1983), growing and finishing steers were fed corn silages of various grain contents as all corn silage diets or with various levels of added grain. The all-silage diets contained 27, 43, and 49% grain. Addition of 39% of the diet DM as whole high-moisture corn to each silage produced silage diets that contained 55, 64, and 68% grain. Two additional diets of 91 and 96% grain were also compared. Pooled data from two years showed that average daily gains increase .009 kg/percentage unit increase in grain level between 30 and 70% grain and feed required/unit of gain decreased .058 kg of diet DM/percentage unit increase in grain over the same range. As grain content in the all-silage diets increased from 30 to 50%, gains increased 17.4% (.99 vs .82 kg/day) and feed efficiency improved 12.3% (8.38 vs 9.55 kg of DM/kg of gain). Steers fed the high concentrate diet with 90% grain gained 6.6% faster (1.24 vs 1.16 kg/day) and required 16.0% less feed per unit of gain (6.05 vs 7.22 kg of DM/kg of gain) than those fed 70% grain. The source of grain (whether added grain or grain in silage) did not influence cattle performance. Dry matter intake remained relatively constant as the percent grain in the diet increased, but was dramatically reduced for steers fed high concentrate diets. Carcass characteristics, such as carcass fat, fat thickness, and dressing percentage were influenced by grain in the diet. However, marbling, quality grade, yield grade, rib eye area, and kidney, heart, and pelvic fat were not influenced by diet grain content.

Brethour and Duitsman (1966b) fed calves Frontier 210 seedless forage sorghum along with grain added pre- and post-ensiling. Three treatments were used: (1) Frontier 210 forage sorghum; (2) Frontier 210 plus 250 lbs. of rolled sorghum grain per ton of pre-ensiled material, added at time of ensiling; (3) Frontier 210 silage, plus rolled sorghum grain added at time of feeding equal to level of grain in treatment 2. Dry matter intake favored the silage with grain added at the time of ensiling (12.1, 14.4, and 12.7 lbs. DM/day for treatments 1, 2, and 3 respectively). Gain was highest when the grain was added at ensiling (9% faster than grain added at feeding), but grain added at feeding also gave higher gain than the control sorghum silage (1.95 vs 1.40 lbs./day). The most efficient gain was produced by treatment 2, while the least efficient was by treatment 1 (6.81 vs 8.66 lb DM/lb. gain). One possible reason for the better performance of the silage with grain added at ensiling is that the addition of grain raised the DM content of the silage from 25.7 to 32.0%, thus producing an environment in the silo for more favorable fermentation.

Smith et al. (1966) obtained similar results, with the addition of grain producing improved cattle performance. However, sorghum grain added at pre- and post-ensiling gave identical cattle performance. Sorghum grain, that was ground prior to ensiling or feeding, gave better performance than grain added whole.

In the first two experiments by McCullough et al. (1981), corn silage harvested at the bloom stage were fed with three levels of grain. Rations were calculated to provide NEm and NEg intake for 1.00, 2.00, and 3.00 lbs. average daily gain. Performance of 550 lb. growing steers was at or above the level of calculated gain for both sorghum and corn silages. The data indicated that the cattle responded in direct proportion to the intake of NE gain. The authors stated that the effects of grain addition on energy value and digestibility of sorghum silage-based rations were apparently additive. Animal performance for sorghum silage would be expected to reflect total NEg intake. The major difference between corn and sorghum silages thus becomes the grain content of the respective silages.

In the second experiment, DeKalb FS24 forage sorghum was harvested at the bloom stage and ensiled in a conventional upright silo. Steer calves (616 lbs.) were fed isonitrogenous diets formulated to provide grain to silage ratios (DM basis) of: 15:85; 30:70; 45:55; 60:40; and 75:25. Diets containing 15 and 30% grain produced comparable gain (1.55 vs 1.70 lbs./day) while the greatest gains were produced by 60% grain (2.40 lbs./day). Gain increased with the addition of grain up to 60% level. The diet containing 75% grain showed a reduction in gain from the 60% grain diet (2.06 vs 2.40 lbs./day), as a result, performance was no better than from the diet containing 45% grain. Dry matter intake increased with grain addition, with 75% grain having the highest intake (23.6 lbs. of DM/day). Feed efficiencies were about the same for all diets, except the diets with 30 and 75% grain, which required 1.31 and 1.71 lbs. of DM more/lb. of gain than the other three diets.

Hart (1987) conducted a metabolism trial using 300 kg steers to evaluate the effect of grain addition on sorghum silage utilization. An intermediate height forage sorghum silage was fed with five levels of ground sorghum grain (0, 15, 30, 45, and 60% of the diet DM). Dry matter intake was increased by grain supplementation regardless of the level; however, the highest DM intake was for the 45% grain diet. Dry matter digestibility was relatively high for the all-silage diet (59.4%) and was attributed to the high grain content of the silage. The DM and organic matter digestibilities were increased by the first two increments of grain. Further additions of grain, however, tended to decrease digestibilities. The increases were primarily due to increased digestibilities of the NDF and cell content fractions. Digestibility of ADF also increased over the first two increments of grain addition, but not to the extent as NDF digestibility. The depression in digestibilities at higher grain levels were attributed to decreased digestibilities of cell walls and to a lesser extent cell contents. The depressions were primarily due to decreased ADF and hemicellulose digestibilities. Starch digestibilities were unaffected by grain level. The addition of 15% grain to the diet resulted in a 24% increase in intake of digestible DM, however, further grain additions resulted in smaller increases.

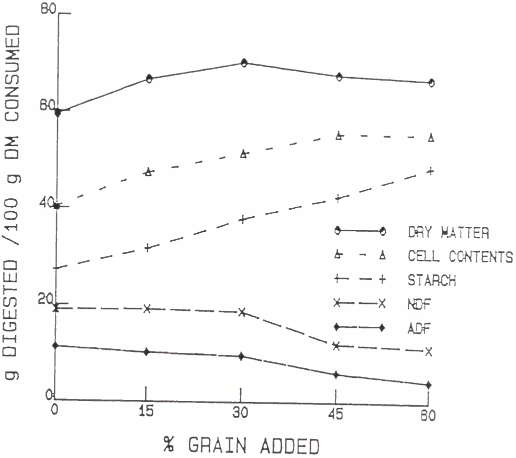

FIGURE 1. GRAMS COMPONENT DIGESTED/100 g DRY MATTER CONSUMED (HART, 1987).

Literature Cited

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, R. Pope, M. Hinds, and J. Hoover. 1983. Whole-plant forage, grain or non-heading sorghum silages, cornlage, and feed flavor supplements for growing calves. Kansas Agr. Exp. Sta. Rpt. of Prog. 427.

Boren, F. W., E.F. Smith, D. Richardson, D.L. Follis, and G.E. Fairbanks. 1962. Factors affecting the feeding value of sorghum silage, 1961-62. A progress report. Kansas Agr. Exp. Sta. Bull. 447.

Brethour, J.R. 1967. Corn silage versus forage sorghum silage for wintering steer calves. Agric. Exp. Sta. Rpt. of Prog. 506. Kansas State University, Manhattan, Kansas.

Brethour, J.R. 1977. Pioneer 931 forage sorghum silage. Kansas Agr. Exp. Sta. Rpt. of Prog. 297.

Brethour, J.R. 1978. Pioneer 931 forage sorghum and Sila-bac preservative. Kansas Agr. Exp. Sta. Rpt of Prog. 326.

Brethour, J.R. and W.W. Duitsman. 1966a. Corn silage compared with a high-grain-type, hybrid forage sorghum silage to winter steer calves. Kansas Agr. Exp. Sta. Bull. 492.

Brethour, J.R. and W.W. Duitsman. 1966b. Study of practices to improve the quality of forage sorghum silage; effect of grain content and dry matter percentage on feeding value of sorghum silage. Kansas Agr. Exp. Sta. Bull. 492.

Browning, C.B., J.W. Lusk, and J.T. Miles. 1961. Comparative feeding value of corn and grain sorghum silages. J. Dairy Sci. 44:1205.

Browning, C.B., and J.W. Lusk. 1966. Comparison of feeding value of corn and grain sorghum silages on the basis of milk production and digestibility. J. Dairy Sci. 49:1511.

Browning, C.B. and J.W. Lusk. 1967. Effect of stage of maturity at harvest on nutritive value of combine-type grain sorghum silage. J. Dairy Sci. 50:81.

Coombs, D.F. and W.A. Nipper. 1984. Beef production from corn silage, grain sorghum silage or wheat haylage. Louisiana Ag. Exp. Sta. Livestock Producer's Day Rpt. Vol. 25.

Cummins, D.G. 1981. Yield and quality changes with maturity of silage-type fodder. Agron. J. 73:988.

Cummins, D.G. and M.E. McCullough. 1969. A comparison of yield and quality of corn and sorghum silage. Georgia Agr. Exp. Sta. Res. Bull. 67.

Cummins, D.G., M.E. McCullough, and J.W. Dobson. 1970. Evaluation of corn and sorghum hybrids for silage. Georgia Agr. Exp. Sta. Res. Rpt. 72.

Danley, M.M. and R.L. Vetter. 1973. Changes in carbohydrate and nitrogen fractions and digestibility of forages: Maturity and ensiling. J. Anim. Sci. 37:994.

Daura, M.T. 1980. Comparison of whole plant grain sorghum silage, grain sorghum head-chop silage, and sorghum grain in rations for lactating cows. M.S. Thesis, Kansas State University.

Dotzenko, A.D., N.E. Humburg, G.O. Hinze, and W.H. Leonard. 1965. Effects of stage of maturity on the composition of various sorghum silages. Colorado Agr. Sta. Tech. Bull. 87.

Fox, D.G., E.W. Klosterman, H.W. Newland, and R.R. Johnson. 1970. Net energy of corn and bird resistant grain sorghum rations for steers when fed as grain or silage. J. Anim. Sci. 30:303.

Gill, D.R., J.R. Martin, and R. Lake. 1976. High, medium, and low corn silage diets with and without monensin for feedlot steer. J. Anim. Sci. 43:363.

Hamma, S.R. 1987. Effects of hybrid and harvest on the yield, composition, and feeding value of forage sorghum silages. M.S. Thesis, Kansas State University, Manhattan, Kansas.

Hart, S.P. 1982. Digestibility of sorghum silage harvested at three cutting heights. Oklahoma Agr. Exp. Sta. Res. Rpt. DP-824. p85.

Hart, S.P. 1987. Associative effects of sorghum silage and sorghum grain diets. J. Anim. Sci. 64:1779.

Jesse, G.W., G.B. Thompson, J.L. Clark, K.G. Weimer, and D.P. Hutcheson. 1976. Effects of various ratios of corn and corn silage and slaughter weight on the performance of steers individually fed. J. Anim. Sci. 43:1049.

Johnson, R.R., V.P. DeFaria, and K.E. McClure. 1971. Effects of maturity on chemical composition and digestibility of bird resistant sorghum plants when fed to sheep as silages. J. Anim. Sci. 33:1102.

Lance, R.O., D.C. Foss, C.R. Krueger, B.R. Bumgardt, and R.P. Niedermeier. 1964. Evaluation of corn and sorghum silages on the basis of milk production and digestibility. J. Dairy Sci. 47:254.

Leighton, R.E., S.Rao, and R.E. Helm. 1969. Comparison of head-chop silage to a similar dry ration for lactating dairy cows. J. Dairy Sci. 52:935.

McCullough, M.E., E.E. Worley, and L.R. Sisk. 1981. Evaluation of sorghum silage as a feedstuff for growing cattle. Agr. Expt. Sta. Res. Rpt. 366. University of Georgia. Athens, Georgia.

Newland, H.W., W.K. Brown, R.J. Deans, C.M.Hansen, and I.W. Comstock. 1964. Center-cut corn silage: A complete energy feed for fattening cattle. Michigan Agr. Exp. Sta. Quart. Bull. 46.374.

Nordquist, P.T. and G.A. Rumery. 1967. Corn and sorghum silage for lactating dairy cows. J. Dairy Sci. 50:1255.

Owen, D.F. and R.D. Furr. 1967. Nitrogen and mineral content of five forage sorghum varieties and the effect of sulphur and minor elements on yield and nutritive value. Texas Agr. Exp. Sta. Spec. Rpt. No. 2.

Owen, F.G. 1962. Effect of stage of maturity on the nutritive value of Atlas sorghum silage for lactating dairy cows. J. Dairy Sci. 45:625.

Owen, F.G. and J.W. Kuhlman. 1967. Effect of maturity on digestibility of forage sorghum silages. J. Dairy Sci. 50:527.

Owen, F.G. J.R. Kuiken, and O.J. Webster. 1962. Value of sterile forage sorghum hybrids as silages for lactating cows. J. Dairy Sci. 45:55.

Owen, F.G., J.T. Miles, W.C. Cowsert, J.W. Lusk, E.W. Custer, and J.T. Cardwell. 1957. Feeding value of corn and sorghum silage for milk production. J. Dairy Sci. 40:1554.

Perry, T.W., and W.M. Beeson. 1976. Ratios of corn to corn silage for finishing beef cattle. J. Anim. Sci. 42:549.

Playne, M.J. and P.J. Skerman. 1964. Influence of height of cutting on yield, nitrogen content and ensilage of sweet sorghum. Empire J. Exptl. Agr. 32:325.

Pund, W.A. 1970. Finishing yearling steers with a high energy grain sorghum silage. Mississippi Agr. Exp. Sta. Bull. 780.

Ritchie, H.D., D.A. Woodburn, R.L. Dingerson, H.E. Henderson, H.D. Woody, and D.R. Strohbehn. 1972. Wintering pregnant heifers in drylot on two varieties of sorghum silage and two sources of supplemental nitrogen. Michigan Agr. Exp. Sta. Res. Rpt. 174.

Rupp, R.A., G.T. Lane, and R.E. Leighton. 1975. Relative digestibilities of two types of sorghums fed as silage. J. Dairy Sci. 58:761

Schmid, A.R., R.D. Goodrich, R.M. Jordan, G.C. Marten, and J.C. Meiske. 1976. Relationships among agronomic characteristics of corn and sorghum cultivars and silage quality. Agron. J. 68:403.

Smith, E.F., G.M. Ward, D. Richardson and H.B. Perry. 1966. The value of grain added to sorghum silage at ensiling. Agr. Exp. Sta. Rpt. of Prog. 493. Kansas State University, Manhattan, Kansas.

Smith, R.L. 1986. Yield, composition, and nutritive value of grain sorghum harvested as silage: Stage of maturity and processing effects. M.S. Thesis, Kansas State University, Manhattan, Kansas.

Smith, R., K. Bolsen, H. Ilg, M. Hinds, R. Pope, J. Dickerson, and J. Hoover. 1984. Effect of type and harvest date on silage feeding value. Kansas Agr. Exp. Sta. Rpt. of Prog. 448.

Smith, R., K. Bolsen, H. Ilg, J. Hoover, and J. Dickerson. 1985. Whole-plant forage, grain, or nonheading sorghum silages for growing cattle. Kansas Agr. Exp. Sta. Rpt. of Prog. 470.

Stallcup, O.T., and J.O. York. 1986. Nutritive value of the grain sorghum plant in cattle diets. Arkansas Agr. Exp. Sta. Bull. 893.

Vanderlip, R.L. and H.E. Reeves. 1972. Growth stages of sorghum [Sorghum bicolor (L.) Moench]. Agron. J. 64:13.

White, J., K.K. Bolsen, G.L. Posler, and J.W. Neill. 1988. Forage sorghum silage dry matter disappearance as influenced by plant proportion. Agron. J. (in press).

Woody, H.D., D.G. Fox, and J.R. Black. 1983. Effect of diet grain content on performance of growing and finishing cattle J. Anim. Sci. 57:717.

Chapter II

YIELD, COMPOSITION, AND NUTRITIVE VALUE OF WHOLE-PLANT GRAIN SORGHUM SILAGE: EFFECTS OF HYBRID, MATURITY, AND GRAIN ADDITION

Experimental Procedures

Experiment 1. Dryland forage and grain sorghum field plots were established near Manhattan, Kansas in the summer of 1985. Four forage sorghum hybrids (Conlee's Cow Vittles, Golden Acres-TE Silomaker, Warner's Sweet Bee, and Warner's Sweet Bee Sterile) and four grain sorghum hybrids (Asgrow Colt, DeKalb 42Y, NC+ 174, and WAC 652G) were compared. They were chosen to represent a range of sorghum pedigrees, which included variation in maturity (season length), plant height, and forage and grain yields. Each hybrid was harvested at three stages of kernel development: late-milk to early-dough (LM), late-dough (LD), and hard-grain (HG). Warner's Sweet Bee Sterile, which produces no grain, was harvested shortly after each harvest of the grain-producing Sweet Bee. The heads of Sweet Bee Sterile were bagged at the first appearance of florets to prevent pollination from surrounding hybrids. The bags were removed once the plant was past the flowering stage.

Treatments were arranged in a split plot design, with four replications. The main plots were the three stages of kernel development at harvest, while the subplots were the individual hybrids. Each subplot consisted of six rows, 9.1 m in length, with 76 cm spacing between rows. Plots were planted on June 13 at a heavy rate and were hand-thinned to 86,114 plants per ha (approximately 15 cm between plants) at about 3 weeks post-emergence.

The soil type was a silty clay loam, which was cropped with grain sorghum the previous year. Anhydrous ammonia was applied to the plot location at the rate of 112 kg per ha, along with a broadcast pre-emergence herbicide prior to planting. On July 24, an insecticide spray was applied to control an infestation of green bugs in the experimental plot area. The growing season was characterized by a wet, cool spring and a cooler and wetter than normal summer and fall.

Data collected for each plot included: days to half bloom, plant height, whole-plant dry matter (DM) yield, and grain yield. Days to half bloom measures maturity and is defined as the number of days between the planting date and the date one-half of the main heads have some florets in bloom. Plant height was measured to the tallest point of the main head immediately prior to harvest. Whole-plant DM yields were determined by harvesting 6.1 m from each of the two center rows with a modified one-row forage harvester. The chopped material from each of the two rows was composited, weighed, and sampled for DM determination. Grain yield was determined by harvesting the grain heads from 6.1 m of one of the remaining inside rows. The heads were then dried and threshed in a stationary thresher. The grain samples were dried to 100% DM and grain yields were calculated on a DM basis.

The chopped material from the two center rows was collected and ensiled in a 19 l capacity laboratory silo, as described by Hinds

(1983). Silos were opened at approximately 110 days post-filling and the silage sampled for chemical analyses. Pre-ensiled material and silages were dried in a forced-air oven at 55 C, and ground through a 1 mm screen in a Wiley mill. Ground silage samples were analyzed for Kjeldahl nitrogen (AOAC, 1984), neutral detergent fiber (NDF), acid detergent fiber (ADF), permanganate lignin, and cellulose (Goering and Van Soest, 1975). Wet silage samples were analyzed for pH, lactic acid by colorimetry (Barker and Summerson, 1941), ammonia-nitrogen by the Conway microdiffusion method (Conway, 1957), and volatile fatty acids (VFA) and ethanol by gas chromatography. Data were statistically analyzed using a general linear models (GLM) procedure (SAS, 1982).

Experiment 2. In 1985, four whole-plant silages were made from three grain sorghum hybrids: DeKalb 42Y, Funk's 550, and Northrup King 2778, and one forage sorghum hybrid, Pioneer 947. Harvest of each hybrid was made at the late-dough stage of kernel development with a precision-cut, self-propelled Field Queen forage chopper. Material from DeKalb 42Y and Northrup King 2778 was ensiled in 4.3 by 18.3 m concrete stave silos; Funk's 550 was ensiled in a 3 by 15 m concrete stave silo; and Pioneer 947 was ensiled in a 2.5 by 23 m Ag Bag^{R}.

The four silages were compared in diets containing two levels of silage. One diet contained 87.6% silage and 12.4% supplement on a DM basis (base diet) and the other diet contained 62.6% silage, 12.4% supplement, and 25% rolled sorghum grain on a DM basis (grain diet). Supplement compositions are presented in Table 1. Each diet was fed to eight crossbred steer and heifer calves (two pens of three steers and one heifer, with an average initial weight of 245 kg). Each diet was formulated to provide 12.0% crude protein (CP) (DM basis), 200 mg of monensin per calf daily, and to meet the minimum NRC (1984) requirements for calcium, phosphorous, and vitamin A. All calves received hormonal implants at the start of the growing period.

To minimize ruminal fill differences, the calves were fed a common forage sorghum silage-based diet at an intake level of 1.75% of body weight (DM basis) for one week prior to starting the experiment. The calves were weighed on two consecutive days after 16 hours without feed or water at the beginning and end of the 70-day feeding period (December 6, 1985 to February 14, 1986).

Each silage was sampled directly from the silo twice weekly. A portion of each sample was dried and the remainder frozen for future analyses. Diet intake was recorded daily for each pen and the quantity of the complete-mixed diet was adjusted daily to assure that fresh feed was always present in the bunks. Feed not consumed was removed, weighed, and discarded as necessary.

Experiment 3. In 1986, five whole-plant silages made from three grain sorghum hybrids: DeKalb 41Y, Funk's 522, NC+174; one forage sorghum hybrid, DeKalb FS-5; and one corn hybrid, Pioneer 3475. Each sorghum hybrid was harvested at the late-dough stage of kernel development and the corn was in the late-dent stage. The hybrids were chopped as described in Experiment 2 and the four sorghum hybrids were ensiled in 2.5 by 23 m Ag Bags^{R}, while the corn was ensiled in a 3 by 15 m concrete stave silo. All silage samples were handled the same as in Experiment 2. The five silages were compared in two diets as described in Experiment 2. Supplement compositions are presented in Table 2. Each diet was fed to eight crossbred steer and heifer calves (two pens of three steers and one heifer, with an average initial weight of 255 kg). The second growing period lasted 80 days (December 12, 1986 to March 1, 1987).

Statistical analyses. In Experiments 2 and 3, cattle performance and silage composition were analyzed using General Linear Models (GLM) procedure (SAS, 1982). Means for comparing differences were determined by the PDIFF (predicted difference) option of the GLM procedure.

Results

Experiment 1. Agronomic characteristics of the eight hybrids, including days to half bloom, plant heights, and harvest dates, are shown in Table 3. The earliest maturing hybrid was WAC 652G with 63 days to half-bloom, while the latest was Cow Vittles with 87 days. On average, the grain sorghum hybrids reached the half bloom stage 11 days before the forage sorghum hybrids. Only Sweet Bee had a season length comparable to the grain sorghums hybrids. At the first harvest date, the tallest hybrid was Cow Vittles, while the shortest was DeKalb 42Y. On average, the forage sorghums were 166 cm taller than the grain sorghums.

An average of 29 days elapsed between the first and third harvest dates for the grain sorghum hybrids and 33 days elapsed between the first and third harvests for the forage sorghums. The first harvest dates tended to be earlier for the grain sorghum hybrids when compared to the forage sorghums.

Effects of hybrid and harvest stage on whole-plant DM and CP contents, whole-plant forage and grain yields, and grain to forage ratios are presented in Table 4. The harvest x harvest stage interactions are reported separately from the main effects in the Appendix and were used as the data for Figures 1 to 4.

The comparison of the main effects on whole-plant DM content showed little variation among the grain sorghum hybrids and all had higher DM than the forage sorghums. The highest DM content among the forage sorghums was for Silomaker, while the lowest was for Sweet Bee

Sterile. The CP content for the grain sorghum hybrids was highest for DeKalb 42Y and WAC 652G, both containing 10.8 percent. The four grain sorghums all had higher CP levels than the four forage sorghums, which ranged from 7.0 (Cow Vittles) to 8.1% (Silomaker). Whole-plant DM yields were higher for the forage sorghum hybrids, and ranged from 13.4 (Sweet Bee) to 15.9 Mg/ha (Sweet Bee Sterile); while the grain sorghums ranged from 12.1 (Asgrow Colt) to 10.9 Mg/ha (WAC 652G). Grain yields were higher for the grain sorghum hybrids. NC+ 174 produced a grain yield which was 2.6 Mg/ha higher than the highest-yielding forage sorghum (Sweet Bee), but only 1.9 Mg/ha higher than the lowest-yielding grain sorghum (DeKalb 42Y). The lowest grain yield, other than Sweet Bee Sterile which produces no grain, was for Cow Vittles (2.3 Mg/ha). The highest grain to forage ratio was for NC+ 174. The ratios for the grain sorghum hybrids ranged from .58 for DeKalb 42Y to .91 for NC+ 174. The ratio for DeKalb 42Y was still .28 higher than the highest forage sorghum ratios for Sweet Bee and Silomaker.

Whole-plant DM content was also effected by harvest stage. The lowest DM content occurred at the late-milk stage, and increased with each advancing harvest, until the hard-grain stage, which had the highest DM content. The reverse was true in CP content. The highest value occurred at the LM stage, with decreases at each subsequent harvest. Harvest stage had no effect on whole-plant DM yields, but harvest stage did effect grain yields. The lowest grain yield occurred at the LM stage, while there was no difference between the

LD and HG stages of maturity. Grain to forage ratio was lowest at the LM stage and highest at the HG stage.

The effects of hybrid and harvest stage on pH, lactic acid, acetic acid, total acids, ethanol, and lactic to acetic acid ratio are presented in Table 5 and Figures 5 and 6. The pH of the silages from the grain sorghums was higher than the pH from the forage sorghums. All 24 silages were below a pH of 5.0, but only the forage sorghums had a pH of less than 4.0. Sweet Bee Sterile had the lowest pH overall, while NC+ 174 had the highest pH. The average across all hybrids showed that pH increased with advancing maturity. Lactic acid content was similar for all silages, except Sweet Bee Sterile which had lactic acid levels much lower than the other seven hybrids. Lactic acid content was highest for the LM stage and decreased as maturity advanced. Acetic acid content of the silages from the four forage sorghum hybrids was higher than that from three of the four grain sorghum hybrids. The exception was NC+ 174, which contained only slightly higher acetic acid levels than the lowest acetic acid containing forage sorghum (Silomaker). Acetic acid content, when averaged across all hybrids, was highest for the LD stage of maturity and lowest for the hard-grain stage. Total fermentation acids were slightly higher in the forage sorghum silages than in the grain sorghums, except Sweet Bee Sterile which was only slightly higher than the lowest total acid content of DeKalb 42Y. Total acid content decreased with advancing maturity. Ethanol content of the grain sorghum silages were similar and showed little variation, while the forage sorghum silages contained both the highest (Sweet Bee Sterile) and the lowest (Cow Vittles) ethanol values overall. Silages made at the HG stage had the lowest ethanol content. The lactic to acetic acid ratios were slightly higher for the grain sorghum silages, except Silomaker which had the third highest ratio. The highest ratio for WAC 652G was .81 higher than the next closest ratio; while at the opposite extreme, Sweet Bee Sterile was .92 lower than the next lowest ratio. When compared across all hybrids, the LM stage silages had the highest lactic to acetic acid ratio, while the LD silages had the lowest.

The effects of hybrid and harvest stage on post-ensiled CP and nitrogen fractions are presented in Table 6 and Figure 7. The CP content of grain sorghum hybrids was highest for DeKalb 42Y and WAC 652G; both contained about 11.2 percent. The four grain sorghums all had higher CP levels than the four forage sorghums, which ranged from 6.0 (Cow Vittles) to 7.7 (Silomaker). Asgrow Colt silages had slightly lower ammonia-nitrogen than silages from the other three hybrids, but all were higher than silages from the four forage sorghums. Crude protein was highest for LM stage and decreased with each advancing stage of maturity. Silages from the LD stage produced the highest ammonia-nitrogen levels, with no differences between the LM and HG silages. When ammonia-nitrogen was expressed as a percentage of the total nitrogen, silages from the four grain sorghums contained the highest percentage, along with Sweet Bee Sterile silages. The LD stage silages had higher ammonia-nitrogen values than the other two stages.

The effects of hybrid and harvest stage on Van Soest constituents are presented in Table 7 and Figures 8 and 9. The three silages from the four forage sorghum hybrids had higher NDF contents than those from the four grain sorghum silages. More variation in NDF content was noted within the four forage sorghums than within the four grain sorghums. The NDF values ranged from 51.1 to 59.0% for the forage sorghums and from 41.4 to 46.3% for the grain sorghums. The average of silages from all eight hybrids at each harvest stage showed the highest NDF values at the LD and HG stages, while the lowest were at the LM stage. The ADF content was much lower for the grain sorghum silages (average 25.55%) compared to the four forage sorghum silage (average 34.9%). The variation within the grain sorghums (24.4 to 26.7%) was also less than variation among the four forage sorghums (31.4 to 40.2%). The ADF values, averaged across all eight hybrids were not affected by harvest stage. Hemicellulose contents tended to be higher in the forage sorghums, however, the highest hemicellulose value was for WAC 652G, and the lowest values for Asgrow Colt and NC+ 174. The highest hemicellulose values occurred in the LD and HG harvest stages, when averaged across all eight hybrids. The highest cellulose contents were in silages from the four forage sorghum hybrids which ranged from 23.7 (Sweet Bee Sterile) to 28.9% (Cow Vittles). The grain sorghums, besides being lower in cellulose content, also showed less variation, ranging from 16.6 (WAC 652G) to 18.2% (DeKalb 42Y). Harvest stage did not effect cellulose content, when averaged across all eight hybrids. Lignin content was much higher for the forage sorghum silages (average 7.1%) when compared to the grain sorghums (average 4.6%). The highest value was for Cow Vittles and the HG stage silages had the highest lignin values among the harvest stages.

Experiment 2. Chemical analyses of four sorghum silages are shown in Table 8. DeKalb 42Y grain sorghum silage had the highest DM content (48.1%), while Pioneer 947 forage sorghum had a significantly lower DM content (35.8%) than the three grain sorghums. The Pioneer 947 silage had the lowest pH of the four hybrids and the highest value was for Northrup King 2778. Lactic acid content was highest for Funk's 550 and Pioneer 947 silages, while Northrup King 2778 contained the lowest lactic acid level. Acetic acid content was highest for Pioneer 947 silage, and lowest for the DeKalb 42Y, but these differences were not statistically significant. Total fermentation acid content was highest for the Pioneer 947 and Funk's 550 silages. The lactic to acetic acid ratio was highest for the forage sorghum silage, while the ratios for the three grain sorghums were virtually the same; however, statistically there was no difference. The DeKalb 42Y silage contained the lowest amount of ethanol. The ammonia-nitrogen values were highest for the three grain sorghum silages.

Crude protein and Van Soest constituents are presented in Table 9. All three grain sorghum silages had significantly higher CP values than the forage sorghum. Pioneer 947 had higher cell wall contents (NDF, ADF, hemicellulose, cellulose, and lignin) than three grain sorghums. The cell wall contents of the Northrup King 2778 and

Funk's 550 grain sorghums were quite similar; however, DeKalb 42Y had the lowest ADF and NDF values of the four silages.

Cattle performance from the eight sorghum silage diets is presented in Table 10. Average daily gain was similar among cattle fed the three grain sorghum silages ranging from 1.11 to 1.15 kg. Pioneer 947 silage produced a daily gain that was less than one kilogram (.92) and significantly lower than gains from the three grain sorghums. Dry matter intake followed the same pattern, with the cattle receiving Pioneer 947 silage ration consuming an average of 1.5 kg less DM per day than cattle receiving the three grain sorghums. The efficiencies of gain were similar for all four sorghum silage diets.

With the addition of 25% rolled sorghum grain, Pioneer 947 silage produced the greatest improvement in cattle performance overall. Of the three grain sorghum silages, Northrup King 2778 showed the best response to grain addition. Dry matter intakes were significantly increased by adding grain to the Pioneer 947 and Northrup King 2778 silages. Although feed efficiency was improved for all four silages, none were statistically significant.

Experiment 3. Chemical analyses of the five silages are presented in Table 11. DeKalb 41Y grain sorghum had the highest DM content (42.7%), while the wettest silage was DeKalb FS-5 forage sorghum (34.1%). The corn silage, Pioneer 3475, had the lowest pH of all the silages and DeKalb FS-5 silage had a lower pH than the three grain sorghums. DeKalb 41Y, which had the highest DM content, also had the highest pH of the five silages. Fermentation acid content (lactic, acetic, and total) was highest for the corn silage and lowest for DeKalb 41Y grain sorghum. Lactic acid content followed a similar pattern as total acids. Acetic acid was relatively low in all silages, ranging from 1.26% for Funk's 522 to 1.83% for the corn silage. DeKalb 41Y and FS-5 silages had the lowest lactic to acetic acid ratios. Ethanol content was similar for silages from all the hybrids, except DeKalb 41Y, which was significantly higher than the other four silages. The ammonia-nitrogen content was highest for NC+ 174 silage and lowest for DeKalb FS-5, but overall ammonia-nitrogen values were relatively low in all five silages.

Crude protein and Van Soest constituents are presented in Table 12. DeKalb FS-5 had significantly higher cell wall contents (except for hemicellulose) than the other four silages. In general, the Van Soest constituents for the grain sorghum and corn silages were similar. Lignin content was nearly identical for the three grain sorghum silages.

Performance of cattle receiving the five silages is presented in Table 13. The corn silage and the silages from two of the three grain sorghums (Funk's 522 and NC+ 174) produced the fastest daily gains, while DeKalb FS-5 gave the slowest gain. Dry matter intake was highest for the grain sorghum silage diets and lowest for the forage sorghum silage. Efficiencies of gain were poorest for cattle fed DeKalb 41Y and FS-5 silages.

The addition of 25% rolled grain sorghum to the five silages had only limited effect on cattle performance. Although DM intake tended to increase for all silages, except DeKalb 41Y, the only significant increase occurred for DeKalb FS-5. Rates and efficiencies of gain were not significantly affected by grain addition. Although feed efficiency was improved by 8% for cattle fed DeKalb 41Y silage, cattle receiving the other two grain sorghum and corn silage diets had poorer efficiencies with grain addition.

Discussion

Experiment 1. Grain sorghum hybrids matured faster than forage sorghum hybrids. On the average, the grain sorghums reached half-bloom 11 days sooner than the forage sorghums and went from first to last harvest 4 days faster than forage sorghum hybrids.

At harvest, the forage sorghum hybrids averaged 166 cm taller than the grain sorghums.

The four grain sorghums, which showed little variation in DM content, had significantly higher DMs than the four forage sorghum hybrids. The DM content of the forage sorghum hybrids was also much more variable than that of the grain sorghums. Besides DM content, the four grain sorghums were superior in crude protein, grain yield, and grain to forage ratio, while whole-plant DM yield was higher in the forage sorghum hybrids. These results are consistent with the data reported by Dotzenko (1965), Schmid (1976), and Smith (1986).

Dry matter content increased with each harvest which agrees with results of other researchers (Browning and Lusk, 1967; Danley and Vetter, 1973; Cummins, 1981). Consistent with work by several others (Johnson et al., 1971; Danley and Vetter, 1973; Hamma, 1987), crude protein decreased with each advancing harvest stage, while DM yield showed no change with maturity. Grain yield and grain to forage ratio increased with maturity which is consistent with data from Browning and Lusk (1967), who found that as grain sorghums were harvested from the milk to the hard-grain stages, the percent of the silage DM represented by the grain doubled.

The silages from all eight hybrids were well preserved and had undergone predominantly homolactic fermentations. The pH values and acid contents were both affected by hybrid. The forage sorghums, with lower DM contents, produced consistently lower pH and generally higher lactic, acetic, and total acid values. This agrees with results of Jackson and Forbes (1970) and Hinds (1983), who showed that as DM content increased, fermentation was restricted and silages had higher pHs and lower acid content. Lactic to acetic acid ratios were about the same for both grain and forage sorghum silages with the exception of Sweet Bee Sterile, which had a significantly lower ratio than the other seven hybrids. The higher acetic acid and ethanol values for the sterile hybrid indicate that its fermentation was the least efficient. Similar results with non-heading sorghums were reported by Smith et al. (1985) and Dickerson et al. (1986).

Silage pH increased while lactic and total acid both decreased with each harvest, which is most likely associated with the accumulation of DM content. The acetic acid content and lactic to acetic ratio did not follow the same trend. The acetic acid was highest at the LD stage and lowest at the HG stage, while the lactic to acetic ratio was lowest at the LD and highest at the LM stage.

Crude protein was affected by both hybrid and harvest stage. The grain sorghums had consistently higher CP values than the forage sorghums (10.3 vs 7.0%). As maturity advanced from LM to HG, CP content decreased. These results are consistent with data reported by Smith (1986) and Hamma (1987).

Grain sorghum silages were dramatically lower in NDF, ADF, cellulose, and lignin compared to the forage sorghums. Among the grain sorghum silages little variation was noted for any of the Van Soest constituents; however, variation was rather large among the forage sorghum hybrids. The late maturing hybrid, Cow Vittles, had the highest values for all Van Soest constituents, with the exception of the hemicellulose, while the early maturing Sweet Bee had the lowest values for the Van Soest constituents. This agrees with work of Smith (1986), Hamma (1987), and Kirch et al. (1987).

Van Soest constituents were not as dramatically affected by maturity as by hybrid, but some trends occurred. Cellulose and ADF contents were not affected by maturity, which is in agreement with research by Smith (1986). The NDF content of the silages showed a significant increase from LM to LD stage, but no differences were shown from LD to HG or from LM to HG stages. Hemicellulose increased from LM to LD, but showed no change after that, while lignin showed an increase at the HG stage. The results would tend to add to an already widely variable consensus about the effects of maturity on Van Soest constituents. Both increasing fiber fractions (Smith, 1986) and decreasing fiber fractions (Black et al., 1980) with advancing maturity have been observed. Most likely, the best explanation lies with results of Cummins (1981) and Pedersen et al. (1982) who found that the effect of maturity on Van Soest constituents differed among sorghum hybrids.

Nitrogen fractions showed differences among hybrids. Grain sorghum silages had the highest percent ammonia-nitrogen and ammonia-nitrogen expressed as a percent of the total nitrogen. The ammonia-nitrogen content of Sweet Bee Sterile, was comparable to that of the grain sorghums when expressed as a percent of the total nitrogen. Perhaps the differences between the two sorghum types can be partially explained by the fact that grain sorghums contain a larger pool of nitrogen which can be changed during the ensiling process. Similar results were reported by Smith (1986) and Kirch et al. (1987). Ammonia-nitrogen values were highest at the LD stage, with no differences between the other two stages of maturity.

Experiment 2. The grain sorghum silages had a higher DM content than the forage sorghum silage, even though all were harvested at the same maturity. The DM content of the grain sorghum hybrids was higher than in Experiment 1, due to the harvest being delayed by inclement weather.

All hybrids were well preserved and of good quality. As observed in Experiment 1, the higher DM grain sorghum silages had higher pH and lower fermentation acid values than the forage sorghums. DeKalb 42Y and Northrup King 2778 had the lowest total acids and the most frequent aerobic deterioration in the silos during the feedout period. Part of this deterioration was likely due to insufficient silage removed from the silage face, as described by Woolford (1984). The silages fed were always kept fresh by removing any deteriorating silage prior to feeding.

As was observed in Experiment 1, the grain sorghum silages had higher CP values and lower Van Soest fiber fractions than the Pioneer 947 forage sorghum.

Performance by the calves fed the four base sorghum silage diets followed similar trends reported by other researchers (Hamma, 1987; Ritchie et al., 1972; and Smith et al., 1984 and 1985). In this experiment and in the previous research cited, the grain sorghum silages produced significantly higher average daily gains and DM intakes than the forage sorghum. The cattle performance from the forage sorghum Pioneer 947, while being lower than the grain sorghums, was considered acceptable at almost one kg/day. The efficiency of gain showed no difference between any of the silage diets.

The addition of grain tended to improve cattle performance in all silage diets, however, the most dramatic improvements were seen in the forage sorghum and NK 2778 grain sorghum. These silages gave improvements of 20% in daily gains, and 10 to 15% improvements in intake with grain addition. Efficiency of gain was not signifigantly affected by adding grain. The positive results shown here are in agreement with research by Brethour and Duitsman (1966), Smith et al. (1966), and McCullough et al. (1981). The generally low response of the four silages with the addition of 25% grain is primarily due to the high grain content of the base diets. Silages from the four hybrids contained from 25 to 40% of the DM from grain as was shown in Experiment 1 and Walter (1985). With the 25% additional grain, the percent of the diet from grain was likely in the range of 50 to 70 percent. Thus, the small improvements in gain may be a result of the diminishing returns noted by McCullough et al. (1981), Jesse et al. (1976), and Hart (1987) as grain in the diet reached levels of 70% of the total diet dry matter.

Experiment 3. As in the Experiments 1 and 2, the grain sorghums produced silages with higher DM contents than the forage sorghum. DeKalb 42Y grain sorghum, had the highest silage DM, but inclimate weather delayed harvest over a week, thus it was harvested past the intended late-dough stage. All five silages were well fermented and aerobically stable. As in Experiments 1 and 2, the forage sorghum silage had a lower pH than any of the three grain sorghum silages. However, the lowest pH and highest acid contents were produced by the corn silage (Pioneer 3475).

The three grain sorghums produced silages higher in CP than both the corn and forage sorghum silages, but the corn was significantly higher than the forage sorghum. At similar stage of maturity, these results are in agreement with those of Dotzenko et al. (1965). Van Soest's fiber fractions were consistently highest for the forage sorghum silage.

When fed to cattle, the silages from the grain sorghums were superior to the forage sorghum silage, which is consistent with the results of Experiment 2. The corn silage produced significantly faster and more efficient gains, and was consumed at a higher level than the forage sorghum silage, which was consistent with results from Brethour (1967), Fox et al. (1970), McCullough et al. (1981), and Bolsen and Smith (1984). The more mature DeKalb 41Y silage produced slower gains, and poorer efficiency than the other two grain sorghum hybrids and poorer cattle performance than the DeKalb 42Y in Experiment 2. Excluding DeKalb 41Y, the remaining two grain sorghum silages produced comparable gains and efficiencies to the corn silage diet, which does not agree with results of Brethour and Duitsman (1966). Dry matter intake of the three grain sorghum silages, on average was about one kg higher than the corn silage diet, which was consistent with results from Bolsen et al. (1983).

The addition of 25% grain sorghum produced significant improvements only in DM intake of the forage sorghum and NC+ 174 silages. Additional grain also tended to increase DM intake in two of the other three silages, while DeKalb 41Y decreased in DM intake. Average daily gains were unaffected by additional grain. Efficiency of gain was in most cases slightly lower or unchanged, only the efficiency of gain of DeKalb 41Y improved by the addition of grain. This general lack of improvement by the addition of 25% grain was, as in Experiment 2, a function of grain content. Though not documented, the three grain sorghum and one corn silage were visibly superior in grain content to the silages of Experiment 2. The NC+ 174 hybrid produced a grain to forage ratio of approximately .90 in Experiment 1, which translates to about 45% of the total DM in the silage was from grain. With the addition of 25% grain, the total DM from grain was about 65 percent. This is in the range where Hart (1987) noted depressed fiber digestibility and McCullough et al. (1981) actually demonstrated reductions in gain and feed efficiency.

Results from the first experiment showed that grain sorghums produced silages that were higher in crude protein, dry matter content, grain content, and grain yield, but lower in DM yield.

Results from Experiments 2 and 3 showed that grain sorghum silages were capable of supporting faster and more efficient gains than forage sorghums and comparable gains and efficiencies to corn silage. The addition of 25% grain to high grain-content silages was of questionable value, but would be more beneficial for low grain-content forage sorghum silages.

In conclusion, although the forage sorghums produced greater whole-plant DM yields, the higher grain and CP content of the grain sorghums would likely offset their lower DM yields. The higher grain-containing silages supported faster gains by growing cattle and their higher CP content meant less supplemental protein was required. These characteristics of grain sorghums, plus their more suitable DM content at harvest and their nutritional plateau at later stages of maturity, make them a viable silage option in growing cattle diets in the Great Plains region.

Literature Cited

AOAC. 1984. Official Methods of Analysis (14th ed.). Association of Official Analytical Chemists, Washington, D.C.

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

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, R. Pope, M. Hinds, and J. Hoover. 1983. Whole-plant forage, grain or non-heading sorghum silages, cornlage, and feed flavor supplements for growing calves. Kansas Agr. Exp. Sta. Rpt. of Prog. 427.

Bolsen, K.K. and R.L. Smith. 1984. Grain, forage, and grainless sorghum silages for growing cattle. Kansas Formula Feed Conference Proceedings.

Brethour, J.R. 1967. Corn silage versus forage sorghum silage for wintering steer calves. Agr. Exp. Sta. Rpt. of Prog. 506. Kansas State University, Manhattan, Kansas.

Brethour, J.R. and W.W. Duitsman. 1966. Corn silage compared with a high-grain-type, hybrid forage sorghum silage to winter steer calves. Kansas Agr. Exp. Sta. Bull. 492.

Browning, C.B. and J.W. Lusk. 1967. Effect of stage of maturity at harvest on nutritive value of combine-type grain sorghum silage. J. Dairy Sci. 50:81.

Conway, E.J. 1957. Microduffusion Analysis and Volumetric LError. Chemical Publishing Co., New York.

Cummins, D.G. 1981. Yield and quality changes with maturity of silage-type fodder. Agron. J. 73:988.

Danley, M.M. and R.L. Vetter. 1973. Changes in carbohydrate and nitrogen fractions and digestibility of forages: Maturity and ensiling. J. Anim. Sci. 37:994.

Dickerson, J., K. Bolsen, S. Hamma, and J. Hoover. 1986. Effect of maturity at harvest on yield, composition, and feeding value of hybrid forage sorghum silages. Kansas Agr. Exp. Prog. Rpt. 494.

Dotzenko, A.D., N.E. Humburg, G.O. Hinze, and W.H. Leonard. 1965. Effects of stage of maturity on the composition of various sorghum silages. Colorado Agr. Sta. Tech. Bull. 87.

Fox, D.G., E.W. Klosterman, H.W. Newland, and R.R. Johnson. 1970. Net energy of corn and bird resistant grain sorghum rations for steers when fed as grain or silage. J. Anim. Sci. 30:303.

Goering, H.K. and P.J. Van Soest. 1975. Forage fiber analysis. USDA Agr. Handbook No. 379.

Hamma, S.R. 1987. Effects of hybrid and harvest on the yield, composition, and feeding value of forage sorghum silages. M.S. Thesis, Kansas State University, Manhattan, Kansas.

Hart, S.P. 1987. Associative effects of sorghum silage and sorghum grain diets. J. Anim. Sci. 64:1779.

Hinds, M. 1983. Effects of non-protein nitrogen, lactobacillus inoculant, and silo type on fermentation and nutritive value of forage sorghum silages. M.S. Thesis, Kansas State University, Manhattan, Kansas.

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

Jesse, G.W., G.B. Thompson, J.L. Clark, K.G. Weimer, and D.P. Hutcheson. 1976. Effects of various ratios of corn and corn silage and slaughter wieght on the performance of steers individually fed. J. Anim. Sci. 43:1049.

Johnson, R.R., V.P. DeFaria, and K.E. McClure. 1971. Effects of maturity on chemical composition and digestibility of bird resistant sorghum plants when fed to sheep as silages. J. Anim. Sci. 33:1102.

Kirch, B., S. Hamma, K. Bolsen, H. Ilg, and J. Hoover. 1987. Whole-plant forage and grain sorghum silage for growing cattle. Kansas Agr. Exp. Sta. Rpt. of Prog. 514.

McCullough, M.E., E.E. Worley, and L.R. Sisk. 1981. Evaluation of sorghum silage as a feedstuff for growing cattle. Agric. Expt. Sta. Research Report 366. University of Georgia. Athens, Georgia.

NRC. 1984. Nutrient requirements of domestic animals, No.2. Nutrient Requirements of Beef Cattle. Sixth revised ed. National Academy of Sciences. National Research Council, Washington, D.C.

Pederson, J.F., A.J. Gorz, F.A. Haskins, and W.M. Ross. 1982. Variability for quality and agronomic traits in forage sorghum hybrids. Crop Sci. 22:853.

Ritchie, H.D., D.A. Woodburn, R.L. Dingerson, H.E. Henderson, H.D. Woody, and D.R. Strohbehn. 1972. Wintering pregnant heifers in drylot on two varieties of sorghum silage and two sources of supplemental nitrogen. Michigan Agr. Exp. Sta. Res. Rpt. 174.

SAS. 1982. SAS User's Guide: Statistics. Statistical Analysis System Institute, Inc., Cary, NC.

Schmid, A.R., R.D. Goodrich, R.M. Jordan, G.C. Marten, and J.C. Meiske. 1976. Relationships among agronomic characteristics of corn and sorghum cultivars and silage quality. Agron. J. 68:403.

Smith, E.F., G.M. Ward, D. Richardson and H.B. Perry. 1966. The value of grain added to sorghum silage at ensiling. Agr. Exp. Sta. Rpt. of Prog. 493. Kansas State University, Manhattan, Kansas.

Smith, R.L. 1986. Yield, composition, and nutritive value of grain sorghum harvested as silage: Stage of maturity and processing effects. M.S. Thesis, Kansas State University, Manhattan, Kansas.

Smith, R., K. Bolsen, H. Ilg, M. Hinds, R. Pope, J. Dickerson, and J. Hoover. 1984. Effect of type and harvest date on silage feeding value. Kansas Agr. Exp. Sta. Rpt. of Prog. 448.

Smith, R., K. Bolsen, H. Ilg, J. Hoover, and J. Dickerson. 1985. Whole-plant forage, grain, or nonheading sorghum silages for growing cattle. Kansas Agr. Exp. Sta. Rpt. of Prog. 470.

Walter, T.L. 1985. Kansas Sorghum Performance Tests. Kansas Agr. Exp. Sta. Bull. 490.

Woolford, M.K. 1984. Managing aerobic deterioration in silage. Silage Management. National Feed Ingredients Association, pp. 42-77.

TABLE 1. COMPOSITION OF SUPPLEMENTS FED IN EXPERIMENT 2

Ingredient	A[1]	B+[2]	C[3]	D+[4]
	% on a DM basis			
Grain sorghum rolled (IFN 4-20-893)	74.15	89.05	29.65	78.55
Soybean meal (IFN 5-20-637)	13.50	5.80	58.70	16.50
Limestone (IFN 6-01-065)	1.85	1.20	2.20	1.25
Urea (IFN 5-05-070)	2.50	.835	2.50	.835
Dicalcium phosphate (IFN 6-01-080)	4.35	1.25	3.30	1.00
Salt (IFN 6-04-152)	2.00	.65	2.00	.65
Tallow (IFN 4-00-376)	1.00	1.00	1.00	1.00
Vitamin premix[a]	.20	.0665	.20	.0665
Trace mineral premix[b]	.25	.085	.25	.085
Monensin	.185	.0615	.185	.0615

[1] Fed with Funk's 550, Northrup King 2778, and DeKalb 42Y.
[2] Fed with Funk's 550, Northrup King 2778, and DeKalb 42Y plus grain.
[3] Fed with Pioneer 947.
[4] Fed with Pioneer 947 plus grain.
[a] Formulated to supply 25,000 IU of vitamin A, 3500 IU of vitamin D, and 30 IU of vitamin E per head per day.
[b] Contained 11% Ca, 10% Mn, 10% Zn, 1% Cu, 0.3% I, and .1% Co.

TABLE 2. COMPOSITION OF SUPPLEMENTS FED IN EXPERIMENT 3

Ingredient	E[1]	F+[2]	G[3]	H+[4]	I[5]	J+[6]
	% on a DM basis					
Grain sorghum rolled (IFN 4-20-893)	29.65	78.55	38.45	80.65	60.65	85.10
Soybean meal (IFN 5-20-637)	58.70	16.50	49.80	14.35	27.20	9.05
Limestone (IFN 6-01-065)	2.20	1.25	2.10	1.25	2.00	1.20
Urea (IFN 5-05-070)	2.50	.835	2.50	.835	2.50	.835
Dicalcium phosphate (IFN 6-01-080)	3.30	1.00	3.50	1.05	4.00	1.25
Salt (IFN 6-04-152)	2.00	.65	2.00	.65	2.00	.65
Tallow (IFN 4-00-376)	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin premix[a]	.215	.07	.215	.07	.215	.07
Trace mineral premix[b]	.25	.085	.25	.085	.25	.085
Monensin	.185	.0615	.185	.0615	.185	.0615

[1] Fed with Pioneer 3475 and DeKalb FS-5.
[2] Fed with Pioneer 3475 and DeKalb FS-5 plus grain.
[3] Fed with NC+ 174 and DeKalb 41Y.
[4] Fed with NC+ 174 and DeKalb 41Y plus grain.
[5] Fed with Funk's 522.
[6] Fed with Funk's 522 plus grain.
[a] Formulated to supply 25,000 IU of vitamin A, 3500 IU of vitamin D, and 30 IU of vitamin E per head per day.
[b] Contained 11% Ca, 10% Mn, 10% Zn, 1% Cu, .3% I, and 0.1% Co.

TABLE 3. AGRONOMIC CHARACTERISTICS OF THE EIGHT HYBRIDS IN EXPERIMENT 1

Hybrid	Sorghum type	Days to half bloom	Plant height[1]	Harvest dates[2]
Asgrow Colt	Grain	78	132.1	S24[a],O2[b],O24[c]
DeKalb 42Y	Grain	69	119.4	S9,S19,O14
NC + 174	Grain	71	134.6	S16,S24,O15
WAC 652G	Grain	63	159.5	S7,S17,O4
Conlee's Cow Vittles	Forage	87	358.1	O2,O14,N7
Golden Acres T-E Silomaker	Forage	84	281.9	S24,O4,N5
Warner Sweet Bee	Forage	74	299.7	S16,S27,O14
Warner Sweet Bee Sterile	Forage	--	271.8	S20,O1,O15

[1] Centimeters.
[2] S=September, O=October, N=November.
[a] Harvest date for late-milk to early-dough stage.
[b] Harvest date for late-dough stage.
[c] Harvest date for hard-grain stage.

TABLE 4. EFFECTS OF HYBRID AND HARVEST STAGE ON WHOLE-PLANT DRY MATTER AND CRUDE PROTEIN CONTENTS, WHOLE-PLANT FORAGE AND GRAIN YIELDS, AND GRAIN TO FORAGE RATIOS OF THE SORGHUM HYBRIDS IN EXPERIMENT 1

Hybrid and harvest stage	Whole-plant			Grain yield[1,2]	Grain: forage
	DM, %	CP, % (DM basis)	DM yield[1]		
Grain sorghum					
Asgrow Colt	33.3^a	9.8^b	12.1^c	6.0^b	$.71^b$
DeKalb 42Y	33.4^a	10.8^a	11.2^{cd}	4.8^c	$.58^c$
NC + 174	33.4^a	9.8^b	12.0^c	6.7^a	$.91^a$
WAC 652G	34.0^a	10.8^a	10.9^d	5.7^b	$.77^b$
Forage sorghum					
Cow Vittles	26.7^{cd}	7.0^e	15.5^a	2.3^f	$.14^e$
Silomaker	28.4^b	8.1^c	15.3^a	4.1^d	$.29^d$
Sweet Bee	27.5^{bc}	7.5^d	13.4^b	3.6^e	$.30^d$
Sweet Bee Sterile	25.9^d	7.7^d	15.9^a	----	----
Harvest stage					
LM	26.0^z	9.4^x	13.3	3.5^y	$.36^z$
LD	28.6^y	8.9^y	13.6	4.3^x	$.46^y$
HG	36.3^x	8.5^z	13.0	4.5^x	$.56^x$
H x HS (P<)[3]	.0001	.0028	----	.0001	.0001
Standard error	1.5	.5	.5	.5	.11

[1] Mg/hectare.
[2] Adjusted to 12.5% moisture.
[3] H x HS = Hybrid by harvest stage interaction.
abcdef Hybrid means with different superscripts differ (P<.05).
xyz Harvest stage means with different superscripts differ (P<.05).

FIGURE 1. EFFECTS OF HYBRID AND HARVEST STAGE ON WHOLE-PLANT DRY MATTER CONTENT (%) OF THE GRAIN AND FORAGE SORGHUM HYBRIDS IN EXPERIMENT 1

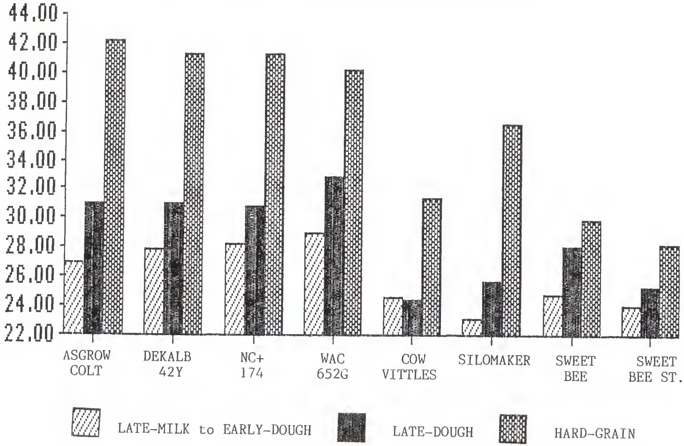

FIGURE 2. EFFECTS OF HYBRID AND HARVEST STAGE ON CRUDE PROTEIN CONTENT (% OF THE WHOLE-PLANT DM) OF THE GRAIN AND FORAGE SORGHUM HYBRIDS IN EXPERIMENT 1

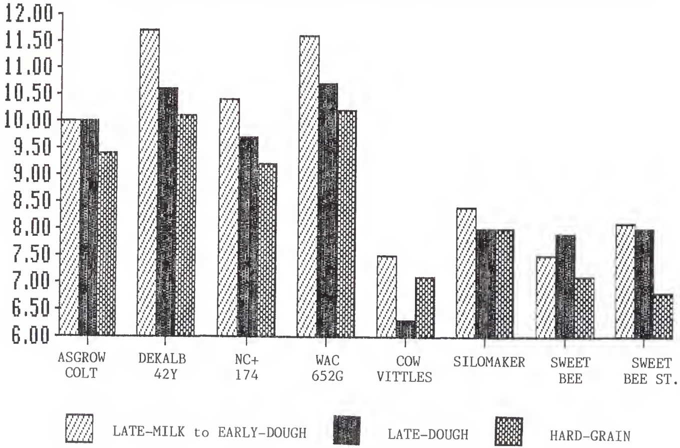

FIGURE 3. EFFECTS OF HYBRID AND HARVEST STAGE ON GRAIN YIELD (Mg/Ha) OF THE GRAIN AND FORAGE SORGHUM HYBRIDS IN EXPERIMENT 1

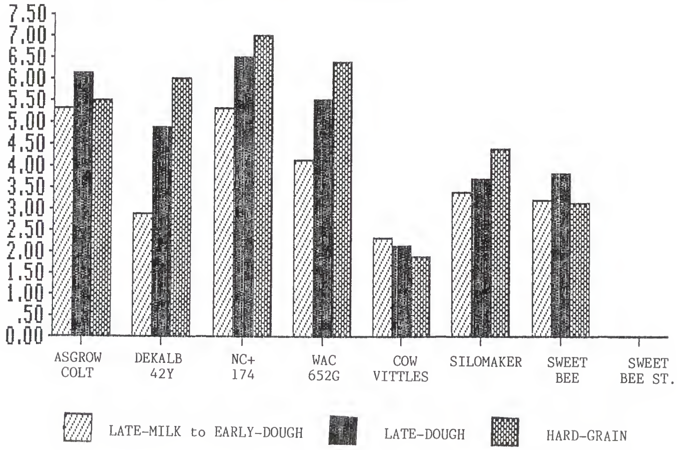

FIGURE 4. EFFECTS OF HYBRID AND HARVEST STAGE ON GRAIN:FORAGE RATIO OF THE GRAIN AND FORAGE SORGHUM HYBRIDS IN EXPERIMENT 1

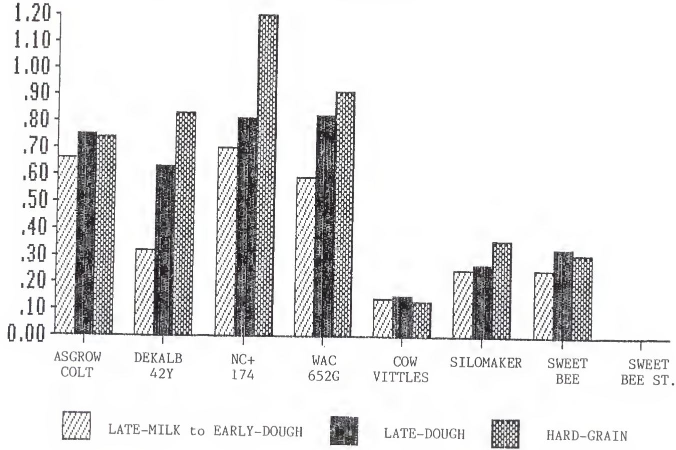

TABLE 5. EFFECTS OF HYBRID AND HARVEST STAGE ON pH AND FERMENTATION PRODUCTS OF THE SORGHUM SILAGES IN EXPERIMENT 1

Hybrid and harvest stage	pH	Fermentation acids Lactic	Acetic	Total	Ethanol	Lactic: acetic
		% on a DM basis				
Grain sorghum						
Asgrow Colt	4.03^{c}	5.37^{abc}	1.50^{de}	6.88^{bc}	$.51^{c}$	3.65^{b}
DeKalb 42Y	4.07^{b}	4.71^{cd}	1.57^{de}	6.28^{c}	$.50^{c}$	3.17^{bc}
NC+ 174	4.15^{a}	4.90^{bcd}	1.75^{bcd}	6.66^{bc}	$.44^{cd}$	3.50^{bc}
WAC 652G	4.09^{b}	5.88^{a}	1.43^{e}	7.30^{ab}	$.50^{c}$	4.46^{a}
Forage sorghum						
Cow Vittles	3.78^{e}	5.58^{ab}	1.90^{abc}	7.46^{ab}	$.34^{d}$	2.96^{c}
Silomaker	3.94^{d}	5.76^{a}	1.65^{cde}	7.42^{ab}	$.44^{cd}$	3.62^{b}
Sweet Bee	3.78^{e}	6.00^{a}	1.97^{ab}	7.98^{a}	$.73^{b}$	2.97^{c}
Sweet Bee St.	3.76^{e}	4.31^{d}	2.20^{a}	6.51^{bc}	$.98^{a}$	2.04^{d}
Harvest stage						
LM	3.86^{z}	6.42^{x}	1.73^{y}	8.15^{x}	$.71^{x}$	3.94^{x}
LD	3.98^{y}	5.01^{y}	1.98^{x}	6.98^{y}	$.66^{y}$	2.78^{z}
HG	4.01^{x}	4.51^{z}	1.53^{z}	6.05^{z}	$.29^{z}$	3.17^{y}
H x HS (P<)[1]	.0001	----	.0001	----	.0001	.0007
Standard error	.04	1.03	.38	1.21	.18	.75

[1] Hybrid by harvest stage interaction.
abcde Hybrid means with different superscripts differ (P<.05).
xyz Harvest stage means with different superscripts differ (P<.05).

FIGURE 5. EFFECTS OF HYBRID AND HARVEST STAGE ON THE pH OF THE GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

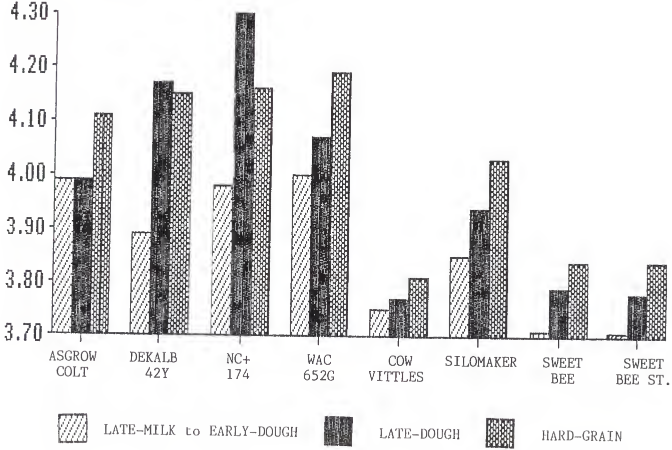

FIGURE 6. EFFECTS OF HYBRID AND HARVEST STAGE ON THE LACTIC TO ACETIC ACID RATIO OF THE GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

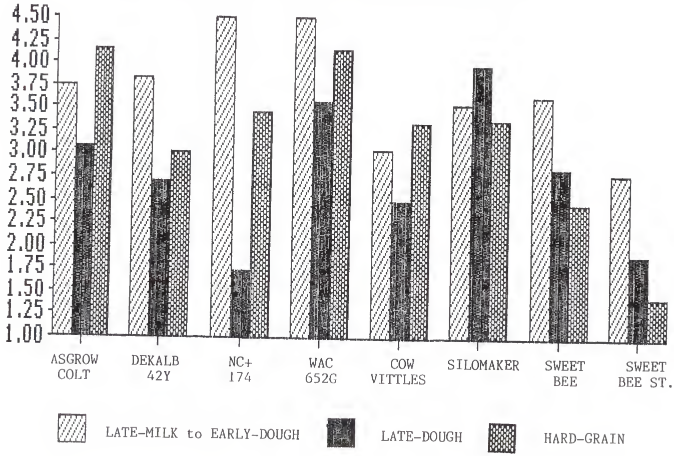

TABLE 6. EFFECTS OF HYBRID AND HARVEST STAGE ON CRUDE PROTEIN AND NITROGEN FRACTIONS OF THE SORGHUM SILAGES IN EXPERIMENT 1

Hybrid and harvest stage	Crude protein	Ammonia-nitrogen	Ammonia-nitrogen
	— % of the silage DM —		% of total N
<u>Grain sorghum</u>			
Asgrow Colt	$.95^{b}$	$.10^{b}$	6.6^{bc}
DeKalb 42Y	11.2^{a}	$.12^{a}$	6.6^{bc}
NC+174	9.5^{b}	$.12^{a}$	7.7^{a}
WAC 652G	11.1^{a}	$.13^{a}$	7.4^{ab}
<u>Forage sorghum</u>			
Cow Vittles	6.0^{e}	$.05^{d}$	5.5^{de}
Silomaker	7.7^{c}	$.06^{cd}$	4.7^{ef}
Sweet Bee	7.1^{d}	$.05^{d}$	4.1^{f}
Sweet Bee Sterile	7.3^{cd}	$.07^{c}$	6.2^{cd}
<u>Harvest stage</u>			
LM	9.2^{x}	$.08^{y}$	5.6^{y}
LD	8.7^{y}	$.10^{x}$	6.7^{x}
HG	8.2^{z}	$.08^{y}$	6.0^{y}
H x HS (P<)[1]	.0083	.0001	.0001
Standard error	.5	.02	.01

[1] Hybrid by harvest stage interaction.
[abcdef] Hybrid means with different superscripts differ (P<.05).
[xyz] Harvest stage means with different superscripts differ (P<.05).

FIGURE 7. EFFECTS OF HYBRID AND HARVEST STAGE ON PROTEIN CONTENT (% OF THE SILAGE DM) OF THE GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

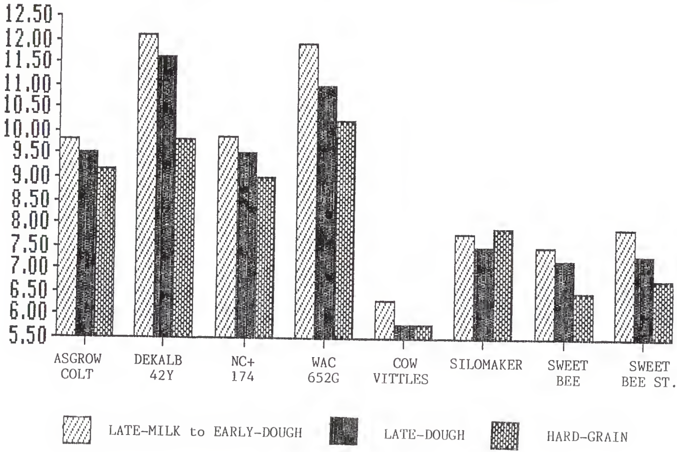

TABLE 7. EFFECTS OF HYBRID AND HARVEST STAGE ON VAN SOEST CONSTITUENTS OF THE SORGHUM SILAGES IN EXPERIMENT 1

Hybrid and harvest stage	Van Soest constituents[1]				
	NDF	ADF	HC	CEL	LIG
	% of the silage DM				
Grain sorghum					
Asgrow Colt	41.8^{f}	25.8^{de}	15.9^{c}	17.7^{ef}	4.4^{e}
DeKalb 42Y	46.3^{e}	26.7^{d}	19.6^{b}	18.2^{e}	4.9^{d}
NC + 174	41.4^{f}	25.3^{e}	16.1^{c}	16.9^{fg}	4.8^{d}
WAC 652G	45.3^{e}	24.4^{e}	20.9^{a}	16.6g	4.4^{e}
Forage sorghum					
Cow Vittles	59.0^{a}	40.2^{a}	18.8^{b}	28.9^{a}	8.4^{a}
Silomaker	54.8^{b}	34.4^{b}	19.2^{b}	25.0^{b}	7.4^{b}
Sweet Bee	51.1^{d}	31.4^{c}	19.7^{ab}	22.5^{d}	6.2^{c}
Sweet Bee Sterile	52.9^{c}	33.6^{b}	19.3^{b}	23.7^{c}	6.3^{c}
Harvest stage					
LM	48.4^{y}	30.3	17.8^{y}	21.3	5.6^{x}
LD	49.6^{x}	30.1	19.4^{x}	21.3	5.8^{x}
HG	49.2^{xy}	30.3	18.9^{x}	21.0	6.1^{y}
H x HS ($P<$)[2]	.0006	.0001	.0001	.0001	.0001
Standard error	2.2	1.7	1.6	1.3	.4

[1] NDF=neutral detergent fiber, ADF=acid detergent fiber, HC=hemicellulose, CEL=cellulose, LIG=lignin.
[2] Hybrid by harvest stage interaction.
[abcdef] Hybrid means with different superscripts differ ($P<.05$).
[xyz] Harvest stage means with different superscripts differ ($P<.05$).

FIGURE 8. EFFECTS OF HYBRID AND HARVEST STAGE ON NEUTRAL DETERGENT FIBER CONTENT (% OF THE SILAGE DM) OF THE GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

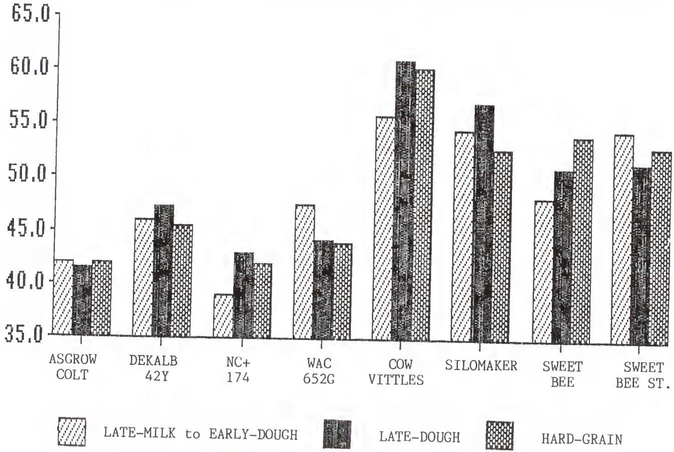

FIGURE 9. EFFECTS OF HYBRID AND HARVEST STAGE ON ACID DETERGENT FIBER CONTENT (% OF THE SILAGE DM) OF THE GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

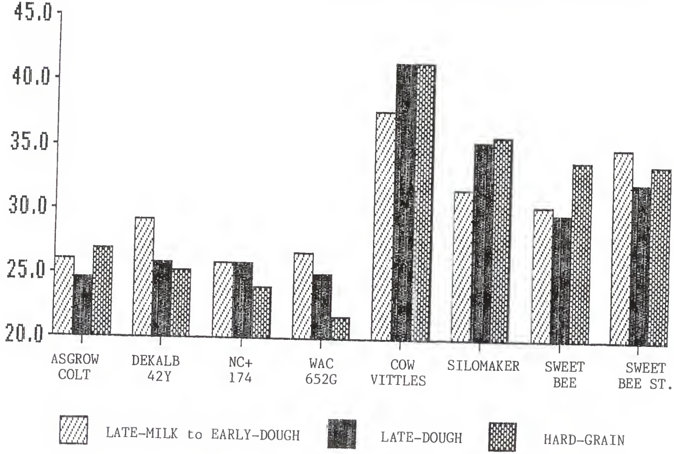

TABLE 8. EFFECT OF SORGHUM HYBRID ON DRY MATTER CONTENT, pH, FERMENTATION ACIDS, ETHANOL, AND AMMONIA-NITROGEN OF THE SILAGES IN EXPERIMENT 2

Item	DeKalb 42Y	Funk's 550	Northrup King 2778	Pioneer 947	SE
Silage DM, %	48.1[a]	41.6[b]	41.0[b]	32.8[c]	1.2
pH	4.37[ab]	4.25[b]	4.49[a]	4.03[c]	.10
	% of the silage DM				
Lactic acid	3.61[bc]	4.38[ab]	2.79[c]	4.90[a]	.62
Acetic acid	1.37	1.81	1.97	1.25	NS
Total acids	5.04[b]	6.22[a]	4.78[b]	6.22[a]	.52
Lactic:acetic	2.66	2.67	2.50	4.07	NS
Ethanol	.12[b]	.25[a]	.21[a]	.20[ab]	.06
Ammonia-nitrogen	.16[a]	.16[a]	.14[a]	.06[b]	.01

[abcd] Means with different superscripts differ ($P<.05$).

TABLE 9. EFFECT OF SORGHUM HYBRID ON CRUDE PROTEIN AND VAN SOEST CONSTITUENTS OF THE SILAGES IN EXPERIMENT 2

Item	DeKalb 42Y	Funk's 550	Northrup King 2778	Pioneer 947	SE
Crude protein	10.1^{c}	11.6^{a}	10.7^{b}	7.6^{d}	.3
Acid detergent fiber	18.3^{c}	21.5^{b}	19.9^{bc}	33.8^{a}	1.5
Neutral detergent fiber	36.9^{c}	43.5^{b}	40.4^{bc}	58.2^{a}	3.2
Hemicellulose	18.5	22.0	20.5	24.4	NS
Cellulose	13.8^{b}	15.2^{b}	14.9^{b}	24.5^{a}	.9
Lignin	3.1^{b}	3.6^{b}	3.2^{b}	6.6^{a}	.5

^{abc} Means with different superscripts differ ($P<.05$).

Table 10. PERFORMANCE BY CALVES FED THE EIGHT SORGHUM SILAGE DIETS IN EXPERIMENT 2

Item	DeKalb 42Y	Funk's 550	Northrup King 2778	Pioneer 947	SE
No. of calves	16	16	16	16	
Initial wt, kg	246	243	246	244	
Avg. daily gain, kg	1.11^{a}	1.15^{a}	1.12^{a}	$.92^{b}$	.19
(w/25% grain)	1.25	1.25	1.33*	1.10**	
Daily DM intake, kg	8.21^{a}	8.02^{a}	8.07^{a}	6.63^{b}	.55
(w/25% grain)	8.42	8.45	8.75*	7.61*	
Feed/gain	7.5	7.0	7.2	7.2	NS
(w/25% grain)	6.7	6.8	6.6	6.9	

[abc] Means with a different superscripts differ (P<.05).
* Means differ from the respective base diet (P<.05).
** Means differ from the respective base diet (P<.10).

TABLE 11. EFFECT OF HYBRID ON DRY MATTER CONTENT, pH, FERMENTATION ACIDS, ETHANOL, AND AMMONIA-NITROGEN OF THE SILAGES IN EXPERIMENT 3

Item	DeKalb 41Y	Funk's 522	NC+ 174	DeKalb FS-5	Pioneer 3475	SE
Silage DM, %	42.7[a]	36.9[c]	38.1[b]	34.1[d]	38.0[b]	.8
pH	4.16[a]	3.95[c]	4.08[b]	3.87[d]	3.63[a]	.06
	% of the silage DM					
Lactic acid	4.43[c]	6.06[b]	6.04[b]	4.96[c]	8.35[a]	.87
Acetic acid	1.49[b]	1.26[b]	1.54[ab]	1.50[b]	1.83[a]	NS
Total acid	5.98[c]	7.32[b]	7.61[b]	6.46[bc]	10.28[a]	.99
Lactic to acetic	3.42[b]	4.91[a]	4.12[ab]	3.62[b]	4.95[a]	.74
Ethanol	.41[a]	.33[b]	.32[b]	.26[b]	.32[b]	.06
Ammonia-nitrogen	.10[b]	.12[ab]	.13[a]	.05[c]	.10[b]	.02

[abcd] Means with different superscripts differ ($P<.05$).

TABLE 12. EFFECT OF HYBRID ON CRUDE PROTEIN AND VAN SOEST CONSTITUENTS OF THE SILAGES IN EXPERIMENT 3

Item	DeKalb 41Y	Funk's 522	NC+ 174	DeKalb FS-5	Pioneer 3475	SE
Crude protein	8.41^{c}	9.85^{a}	9.21^{b}	7.03^{e}	7.94^{d}	.22
Acid detergent fiber	20.31^{c}	22.63^{b}	21.40^{bc}	32.24^{a}	21.71^{b}	1.01
Neutral detergent fiber	48.46^{b}	48.96^{b}	38.01^{c}	59.24^{a}	39.42^{c}	2.95
Hemicellulose	28.15^{a}	26.33^{a}	16.40^{b}	27.00^{a}	17.70^{b}	2.63
Cellulose	14.51^{c}	16.60^{b}	15.14^{c}	23.50^{a}	---	.80
Lignin	3.34^{b}	3.31^{b}	3.36^{b}	5.52^{a}	---	.26

^{abcde} Means with different superscripts differ (P<.05).

TABLE 13. PERFORMANCE BY CALVES FED THE 10 SILAGE DIETS IN EXPERIMENT 3

Item	DeKalb 41Y	Funk's 522	NC+ 174	DeKalb FS-5	Pioneer 3475	SE
No. of calves	16	16	16	16	16	
Initial wt, kg	256	253	253	258	256	
Avg. daily gain, kg	$.98^{b}$	1.18^{a}	1.20^{a}	$.77^{c}$	1.22^{a}	.16
(w/25% grain)	1.03	1.18	1.24	.87	1.22	
Daily DM intake, kg	8.98^{a}	8.66^{a}	8.48^{a}	6.99^{c}	7.76^{b}	.72
(w/25% grain)	8.75	9.21	9.39	7.71*	8.35	
Feed/gain	9.3^{b}	7.3^{a}	7.1^{a}	9.0^{a}	6.4^{a}	.4
(w/25% grain)	8.6	7.8	7.6	8.9	6.8	

^{abc} Means with different superscripts differ ($P<.05$).
* Mean differs from the respective base diet ($P<.05$).

APPENDIX TABLE 1. WHOLE-PLANT DRY MATTER AND CRUDE PROTEIN CONTENTS, WHOLE-PLANT FORAGE AND GRAIN YIELDS, AND GRAIN TO FORAGE RATIOS OF THE 24 GRAIN AND FORAGE SORGHUMS HARVESTED IN EXPERIMENT 1

Hybrid	Harvest stage	Whole-plant			Grain yield[1,2]	Grain: forage
		DM, %	CP, % (DM basis)	DM yield[1]		
Grain sorghum						
Asgrow Colt	LM	26.9^{fg}	10.0^{bcd}	12.1^{ef}	5.3^{cd}	$.66^{def}$
	LD	30.9^{cde}	10.0^{bcd}	12.8^{de}	6.1^{bc}	$.75^{cdef}$
	HG	42.2^{a}	9.4^{de}	11.5^{efg}	5.5^{cd}	$.74^{cde}$
DeKalb 42Y	LM	27.9^{f}	11.7^{a}	10.8^{fg}	2.9^{ij}	$.32^{g}$
	LD	31.0^{cde}	10.6^{b}	11.5^{efg}	4.9^{de}	$.63^{ef}$
	HG	41.3^{a}	10.1^{bc}	11.5^{efg}	6.0^{bc}	$.83^{bcd}$
NC+ 174	LM	28.2^{f}	10.4^{b}	11.5^{efg}	5.3^{cd}	$.70^{cdef}$
	LD	30.8^{cde}	9.7^{cde}	13.0^{de}	6.5^{ab}	$.81^{bcd}$
	HG	41.2^{a}	9.2^{e}	11.7^{ef}	7.0^{a}	1.20^{a}
WAC 652G	LM	29.0^{ef}	11.6^{a}	9.9^{g}	4.1^{efg}	$.59^{f}$
	LD	32.9^{c}	10.7^{b}	11.0^{fg}	5.5^{cd}	$.82^{bc}$
	HG	40.2^{a}	10.2^{b}	11.9^{ef}	6.4^{b}	$.91^{b}$
Forage sorghum						
Cow Vittles	LM	24.5^{hi}	7.5^{gh}	16.6^{a}	2.3^{jk}	$.14^{h}$
	LD	24.4^{hi}	6.3^{j}	14.8^{bc}	2.1^{k}	$.15^{h}$
	HG	31.4^{cd}	7.1^{hi}	15.1^{bc}	1.9^{k}	$.13^{h}$
Silomaker	LM	23.1^{i}	8.4^{f}	15.3^{abc}	3.4^{ghi}	$.25^{gh}$
	LD	25.6^{gh}	8.0^{fg}	15.7^{abc}	3.7^{fgh}	$.27^{gh}$
	HG	36.5^{b}	8.0^{fg}	14.8^{bc}	4.4^{ef}	$.36^{g}$
Sweet Bee	LM	24.8^{ghi}	7.5^{ghi}	14.2^{cd}	3.2^{hi}	$.25^{gh}$
	LD	28.0^{f}	7.9^{fg}	13.9^{cd}	3.8^{fg}	$.33^{g}$
	HG	29.8^{de}	7.1^{hi}	12.1^{ef}	3.1^{hi}	$.31^{g}$
Sweet Bee Sterile	LM	24.0^{hi}	8.1^{f}	15.7^{ab}	----	----
	LD	25.3^{gh}	8.0^{fg}	15.9^{ab}	----	----
	HG	28.2^{f}	6.8^{ij}	15.9^{ab}	----	----

[1] Mg/hectare.
[2] Adjusted to 12.5% moisture.
[abcdefghijk] Means within a column with different superscripts differ (P<.05).

APPENDIX TABLE 2. pH AND FERMENTATION PRODUCTS OF THE 24 GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

Hybrid	Harvest stage	pH	Fermentation acids: Lactic	Acetic	Total	Ethanol	Lactic: acetic
			% of the silage DM				
Grain sorghum							
Asgrow Colt	LM	3.99^{fg}	6.66	1.87^{cdef}	8.53	$.84^{bcd}$	3.73^{bcde}
	LD	3.99^{fg}	4.45	1.44^{fgh}	5.89	$.56^{efgh}$	3.08^{cdefg}
	HG	4.11^{cd}	5.01	1.21^{gh}	6.22	$.12^{l}$	4.16^{b}
DeKalb 42Y	LM	3.89^{hi}	5.91	1.54^{efgh}	7.45	$.72^{cdef}$	3.82^{bcd}
	LD	4.17^{bc}	4.66	1.93^{bcdef}	6.59	$.61^{defgh}$	2.68^{efghi}
	HG	4.15^{bc}	3.55	1.24^{gh}	4.80	$.18^{jkl}$	3.00^{cdefg}
NC+ 174	LM	3.98^{fg}	6.09	1.25^{gh}	7.34	$.36^{hijkl}$	5.31^{a}
	LD	4.31^{a}	4.75	2.84^{a}	7.60	$.79^{cde}$	1.73^{ij}
	HG	4.16^{bc}	3.86	1.15^{h}	5.03	$.16^{kl}$	3.45^{bcde}
WAC 652G	LM	4.00^{ef}	6.71	1.22^{gh}	7.92	$.43^{ghi}$	5.65^{a}
	LD	4.07^{de}	5.97	1.82^{cdef}	7.79	$.53^{fgh}$	3.58^{bcde}
	HG	4.19^{b}	4.93	1.25^{gh}	6.18	$.54^{fgh}$	4.15^{b}
Forage sorghum							
Cow Vittles	LM	3.75^{lm}	6.46	2.12^{bcd}	8.58	$.39^{ghijk}$	3.05^{cdefg}
	LD	3.77^{lm}	4.61	1.88^{cdef}	6.44	$.40^{ghijk}$	2.49^{fghij}
	HG	3.81^{jkl}	5.66	1.72^{defg}	7.38	$.23^{ijkl}$	3.34^{bcdef}
Silomaker	LM	3.85^{ij}	6.64	1.86^{cdef}	8.50	$.63^{defg}$	3.53^{bcdef}
	LD	3.94^{gh}	5.48	1.55^{efgh}	7.03	$.42^{ghij}$	3.97^{bc}
	HG	4.03^{ef}	5.17	1.55^{efgh}	6.71	$.26^{ijkl}$	3.36^{bcdef}
Sweet Bee	LM	3.71^{mn}	7.92	2.19^{bcd}	10.11	$.83^{bcd}$	3.62^{bcde}
	LD	3.79^{jkl}	5.70	2.02^{bcde}	7.71	$.94^{bc}$	2.85^{defgh}
	HG	3.84^{ijk}	4.40	1.71^{defg}	6.11	$.41^{ghijk}$	2.45^{ghij}
Sweet Bee Sterile	LM	3.67^{n}	4.99	1.81^{cdef}	6.80	1.48^{a}	2.77^{defgh}
	LD	3.78^{kl}	4.43	2.35^{abc}	6.77	1.06^{b}	1.91^{hij}
	HG	3.84^{ijk}	3.51	2.45^{ab}	5.96	$.39^{ghijk}$	1.44^{j}

abcdefghijklmn Means within the same column with different superscripts differ ($P<.05$).

APPENDIX TABLE 3. CRUDE PROTEIN AND NITROGEN FRACTIONS OF THE 24 GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

Hybrid	Harvest stage	Crude protein	Ammonia-nitrogen	Ammonia-nitrogen
		— % of the silage DM —		% of total N
Grain sorghum				
Asgrow Colt	LM	9.8^{cd}	$.126^{bc}$	8.01^{b}
	LD	9.5^{cde}	$.083^{efg}$	5.48^{def}
	HG	9.2^{de}	$.089^{ef}$	6.39^{bcde}
DeKalb 42Y	LM	12.1^{a}	$.130^{bc}$	6.70^{bcd}
	LD	11.6^{ab}	$.149^{ab}$	7.99^{b}
	HG	9.8^{cd}	$.080^{efg}$	5.12^{defg}
NC+ 174	LM	9.9^{cd}	$.115^{cd}$	7.25^{bc}
	LD	9.5^{cde}	$.162^{a}$	10.68^{a}
	HG	9.0^{e}	.077	5.28^{defg}
WAC 652G	LM	11.9^{a}	$.093^{de}$	4.87^{efg}
	LD	11.0^{b}	$.174^{a}$	9.77^{a}
	HG	10.2^{c}	$.123^{bc}$	7.60^{b}
Forage sorghum				
Cow Vittles	LM	6.3^{jk}	$.50^{ij}$	5.43^{defg}
	LD	5.8^{k}	$.49^{j}$	5.31^{defg}
	HG	5.8^{k}	$.055^{ij}$	5.89^{cdef}
Silomaker	LM	7.8^{fg}	$.055^{hij}$	4.46^{fg}
	LD	7.5^{fgh}	$.060^{ghij}$	4.31^{fg}
	HG	7.9^{f}	$.065^{fghi}$	5.22^{defg}
Sweet Bee	LM	7.5^{fgh}	$.053^{ij}$	4.01^{fg}
	LD	7.2^{ghi}	$.041^{j}$	3.62^{g}
	HG	6.5^{ij}	$.050^{ij}$	4.75^{efg}
Sweet Bee Sterile	LM	7.9^{f}	$.055^{hij}$	4.35^{fg}
	LD	7.3^{fghi}	$.075^{efgh}$	6.45^{bcde}
	HG	6.8^{hij}	$.085^{ef}$	7.90^{b}

^{abcdefghijk} Means within a column with different superscripts differ ($P<.05$).

APPENDIX TABLE 4. VAN SOEST CONSTITUENTS OF THE 24 GRAIN AND FORAGE SORGHUM SILAGES IN EXPERIMENT 1

Hybrid	Harvest stage	Van Soest constituents[1]				
		NDF	ADF	HC	CEL	LIG
		% of the silage DM				
Grain sorghum						
Asgrow Colt	LM	41.9^{kl}	26.0^{ij}	15.9^{ij}	17.8^{i}	4.6^{i}
	LD	41.4^{kl}	24.6^{ij}	16.8^{hij}	17.5^{ij}	3.8^{k}
	HG	42.0^{kl}	26.9^{hi}	15.2^{jk}	17.9^{i}	4.8^{hi}
DeKalb 42Y	LM	46.0^{hij}	29.1^{gh}	17.0^{ghij}	19.9^{h}	5.2^{fgh}
	LD	47.3^{hi}	25.9^{ij}	21.4^{ab}	8.0^{i}	4.6^{i}
	HG	45.5^{hij}	25.3^{ij}	20.2^{bcde}	16.8^{ij}	4.9^{hi}
NC+ 174	LM	39.1^{l}	25.9^{ij}	13.2^{k}	17.7^{i}	4.6^{i}
	LD	43.0^{jk}	25.9^{ij}	17.1^{fghij}	17.4^{ij}	5.2^{gh}
	HG	42.0^{kl}	24.0^{j}	18.0^{efghi}	15.7^{jk}	4.4^{ij}
WAC 652G	LM	47.5^{h}	26.7^{hi}	20.8^{abcd}	18.1^{i}	4.6^{i}
	LD	44.3^{ijk}	25.1^{ij}	19.2^{bcdef}	17.3^{ij}	4.5^{ij}
	HG	44.1^{jk}	21.6^{k}	22.6^{a}	14.5^{k}	4.0^{jk}
Forage sorghum						
Cow Vittles	LM	55.7^{cd}	37.8^{b}	17.8^{efghi}	27.0^{b}	7.7^{b}
	LD	61.0^{a}	41.4^{a}	19.6^{bcde}	29.8^{a}	8.5^{a}
	HG	60.3^{ab}	41.5^{a}	18.8^{defgh}	29.7^{a}	8.9^{a}
Silomaker	LM	54.6^{cd}	31.7^{def}	20.4^{abcd}	23.9^{def}	7.0^{c}
	LD	57.1^{bc}	35.5^{bc}	20.3^{abcde}	26.1^{bc}	7.4^{bc}
	HG	52.8^{def}	35.9^{bc}	17.0^{ghij}	25.1^{cd}	7.7^{b}
Sweet Bee	LM	48.2^{gh}	30.5^{efg}	17.8^{efghi}	22.1^{fg}	5.7^{ef}
	LD	51.0^{fg}	29.8^{fg}	21.2^{abc}	21.1^{gh}	6.0^{de}
	HG	54.1^{cdef}	34.0^{cd}	20.1^{bcde}	24.2^{cde}	6.9^{c}
Sweet Bee Sterile	LM	54.4^{cde}	34.9^{c}	19.5^{bcde}	24.2^{cde}	5.6^{efg}
	LD	51.4^{ef}	32.3^{de}	19.1^{cdefg}	23.2^{ef}	6.2^{d}
	HG	52.9^{def}	33.7^{cd}	19.1^{cdefg}	23.7^{def}	7.0^{c}

[1] NDF=neutral detergent fiber, ADF=acid detergent fiber, HC=hemicellulose, CEL=cellulose, LIG=lignin.

[abcdefghijk] Means within a column with different superscripts differ (P<.05).

YIELD, COMPOSITION, AND NUTRITIVE VALUE OF WHOLE-PLANT GRAIN SORGHUM SILAGE: EFFECTS OF HYBRID, MATURITY, AND GRAIN ADDITION

by

Brett Howard Kirch

B. S., University of Nebraska-Lincoln, 1984

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1989

ABSTRACT

In Experiment 1, four grain sorghum (GS) and four forage sorghum (FS) hybrids, which represented a range of pedigrees, were grown under dryland conditions. GS hybrids were: Asgrow Colt, DeKalb 42Y, NC+ 174, and WAC 652G. FS hybrids were Conlee's Cow Vittles, Golden Acres-TE Silomaker, and Warner's Sweet Bee (SB) and Sweet Bee Sterile (SBS). Each hybrid was harvested and ensiled in laboratory silos at three stages of kernel development: late-milk (LM), late-dough (LD), and hard-grain (HG). The sterile hybrid was harvested at the same time as the grain-producing SB hybrid. The experiment was designed as a split-plot (hybrids as main plots and harvest stages as sub-plots) with four replications.

Both agronomic and silage fermentation characteristics were measured. Days to half bloom ranged from 63 to 78 for GS and 74 to 87 for FS hybrids. The GS hybrids averaged 136 cm plant height and 33.5% dry matter (DM) content; FS hybrids, 304 cm and 27.1 percent. Average whole-plant DM yields were higher for FS hybrids (15.0 vs 11.6 Mg per ha) while crude protein (CP) (10.3 vs 7.6%) and grain yield (5.8 vs 3.3 Mg per ha) were higher for the GS hybrids. On average, GS silages had higher pH (4.08 vs 3.82) and lactic to acetic acid (3.7 vs 2.9), but lower lactic acid (5.2 vs 5.4%) and acid detergent fiber (25.6 vs 34.9%) than the FS silages. Harvest stage affected DM content and pH, each increasing with advancing harvest stage; and CP and lactic acid content, each decreasing with advancing harvest. Hybrid x harvest stage interactions occurred for all characteristics, except DM yield and lactic and total acids content.

In Experiments 2 and 3, whole-plant FS, GS, and corn silages were compared in diets for growing cattle. In Experiment 2, three GS silages (DeKalb 42Y, Northrup King 2778, and Funk's 550) and one FS silage (Pioneer 947) were fed for 70 days. In Experiment 3, three GS silages (DeKalb 41Y, Funk's 522, and NC+ 174), one FS silage (DeKalb FS-5), and one corn silage (Pioneer 3475) were fed for 80 days.

All hybrids were grown under dryland conditions and harvested at late-dough stage of kernel development for the sorghums and late-dent stage for the corn. Each silage was fed to 16 mixed-breed steers and heifers, four per pen (Experiment 2, 245 kg initial wt.; Experiment 3, 255 kg). The fixed-percentage (DM basis) diets for two pens contained 87.6% silage and 12.4% supplement, while 25.0% rolled sorghum grain replaced an equal amount of silage in the diet for the other two pens. All diets were 12.0% CP and provided 200 mg of monensin per animal daily. In Experiment 2, all three GS silages produced faster average daily gains (ADG) and higher DM intakes than the FS silage. Feed per gain (F/G) was unaffected by silage treatment. The addition of grain improved cattle performance only for Northrup King 2778 and Pioneer 947 silages. In Experiment 3, GS and corn silages produced faster ADGs and higher DM intakes and better F/Gs than the FS silage. All GS and corn silages produced an ADG of about 1.20 kg, except DeKalb 41Y, which was harvested beyond the LD stage due to rainy weather conditions. The addition of grain had little effect on cattle performance, although DM intakes of the DeKalb FS-5 and NC+ 174 silages were increased by about 10 percent.

Results of these experiments show grain sorghum to be a feasible alternative to traditional corn and forage sorghum as a whole-plant silage for growing cattle.