

## Chemical Composition, Ensiling Characteristics, and Apparent Digestibility of Summer Annual Forages in a Subtropical Double-Cropping System with Annual Ryegrass<sup>1</sup>

J. D. Ward,\* D. D. Redfearn,\* M. E. McCormick,\* and G. J. Cuomo†

\*Louisiana State University Agricultural Center, Southeast Research Station, Franklinton 70438

†University of Minnesota,

West Central Research and Outreach Center, Morris 56267

### ABSTRACT

A 2-yr study was conducted to determine the chemical composition and digestibility of silages made from forage sorghum, pearl millet, and tropical corn managed to optimize forage quality. Silages were ensiled in upright concrete silos lined with plastic and fed to heifers to determine in vivo apparent digestibility. Samples were collected before and after ensiling to determine ensiling characteristics and forage quality. After ensiling, tropical corn had the greatest dry matter (DM), the lowest crude protein, and the greatest water-soluble concentrations. Tropical corn silage had a pH of 3.96. The pH of forage sorghum silage was 4.09, and pearl millet had a pH of 4.50. Pearl millet had the lowest concentration of preensiled water-soluble carbohydrate, which likely caused the high pH in the silage. There were no differences among the forages in DM loss during ensiling in yr 2. Heifers fed pearl millet silage consumed more DM, but digestible DM intake was not different among the three groups of heifers. The results of this experiment indicate that pearl millet would be less desirable as a crop intended solely for silage production. Both forage sorghum and tropical corn could be grown specifically for ensiling based on DM digestibility. The decision on which crop to use should be based on factors such as production costs, forage yields, and local growing conditions rather than silage quality.

(**Key words:** silage quality, forage sorghum, tropical corn, pearl millet)

**Abbreviation key:** WSC = water-soluble carbohydrates.

### INTRODUCTION

A consistent supply of high quality forage is essential to economically maintain high levels of milk production. In the southeastern United States, annual ryegrass (*Lolium multiflorum* Lam.) is the primary forage used in many forage systems. It provides high quality forage from late fall through late spring and can be productive into June, depending on temperature and rainfall conditions. In a typical annual ryegrass-based forage system, annual ryegrass is grazed from November through early March. Regrowth can be harvested as haylage, balage, or hay in mid- to late-April. However, ryegrass cannot always supply adequate amounts of forage to provide for year-round forage needs, especially on dairy farms, and other sources of high quality forage are needed. Often, crops grown specifically for silage production fill this need. As dairy farms are increasing in herd size without a concomitant increase in associated land base, it is becoming increasingly difficult for southeastern US dairy producers to supply enough high quality forage without using their forage acres intensively in a double cropping system.

Temperate corn (*Zea mays* L.) probably offers the best combination of yield and forage quality for a silage crop. However, recommended planting dates for temperate corn in the Coastal Plain of the Gulf Coast, range from early March (Cuomo, 1996) to mid-April (Nelson et al., 1977) to maximize yield and quality. Because growth of temperate corn overlaps with the rapid spring growth of ryegrass, temperate corn cannot be double cropped effectively with annual ryegrass.

Three summer annual forage crops that can be planted after annual ryegrass ceases to produce high quality stored forage are forage sorghum (*Sorghum bicolor* (L.) Moench.), pearl millet (*Pennisetum americanum* (L.) Leeke.), and tropical corn. These forages are often referred to as late-summer forage crops because they can be grown later into the summer than temperate corn due to their increased drought and insect resistance. Most importantly, management of sum-

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Corresponding author: J. D. Ward; e-mail: jward@agctr.lsu.edu.

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mer annual forages does not interfere with annual ryegrass production. Therefore, planting these crops following annual ryegrass allows two forage crops to be grown on the same area during different growing periods, thereby increasing total forage production per hectare.

Forage sorghum usually is harvested once following grain development. However, the quality of mature sorghum silage is less desirable than temperate corn silage for high producing dairy cows (McCormick et al., 1990; McCullough et al., 1981). McCormick et al. (1995) reported that forage sorghum, harvested when vegetative, produced higher quality forage than forage sorghum harvested following grain development. In another study (Messman et al., 1992), a combination of pearl millet and alfalfa (*Medicago sativa* L.) silage supported as much milk production as a combination of corn silage and alfalfa silage. However, DMI and BW gain were less for cows fed the pearl millet/alfalfa silage than for those fed the combination of corn silage and alfalfa silage.

Tropical corn germplasm was identified as a source of resistance to insects and potential productivity under adverse weather conditions for use as a late-planted forage crop for the coastal plain of the Southeastern United States (Widstrom et al., 1980). However, limited information exists about the quality of tropical corn silage. Rakes et al. (1992) reported that DMI and FCM production were similar between cattle fed either tropical corn silage or temperate corn silage.

These studies suggest that forage sorghum, pearl millet, and tropical corn crops have the potential to increase the amount of high quality forage produced on a limited land area when double cropped with annual ryegrass. However, differences in the objectives and methods used across studies make it difficult to predict which of these crops would consistently produce the highest quality silage. Therefore, the objective of this study was to compare the chemical composition, ensiling characteristics, and apparent digestibility of pearl millet, forage sorghum, and tropical corn managed to optimize forage quality of each crop.

## MATERIALS AND METHODS

A 2-yr study was conducted to determine the suitability of forage sorghum, pearl millet, and tropical corn as silage crops. Research was conducted at the Louisiana State University AgCenter, Southeast Research Station, near Franklinton. Soils were Tangi silt loam (fine-silty, siliceous, thermic Typic Fragiudults). There were 36 d with measurable precipitation in yr 1 between June 1 and September 15, with a total accumulation of 284 mm. In contrast, there were 45 d with measurable

rainfall in yr 2, with a total accumulation of 441 mm during the 107-d growing period. The average daily high and low temperatures were similar between the years, with an average high of 34 and 33°C for yr 1 and 2, respectively, and an average low of 20.2 and 20.3°C for yr 1 and 2, respectively.

## Silage Production

'Pennleaf' pearl millet, 'NK 300' forage sorghum, and 'X304C' tropical corn were planted June 1, 1995, and May 28, 1996. Pearl millet was drilled at 28 kg of pure live seed per hectare in rows 20 cm apart. Forage sorghum was drilled at 13 kg of pure live seed per hectare in 20-cm rows. Tropical corn was seeded at 58,000 seed per hectare (Cuomo et al., 1998). Pearl millet and forage sorghum were fertilized with 67 kg of N per hectare at planting. Tropical corn was fertilized with 112 kg of N per hectare at planting. All forage species were fertilized with P and K according to soil test recommendations. Pearl millet and forage sorghum were cut in a vegetative stage approximately July 15 at a crop height of approximately 100 cm. Forage was harvested to a 10-cm stubble height with a flail-type mower conditioner. The forage was allowed to wilt in 1.4-m windrows for 24 h, after which it was chopped with a precision-cut forage harvester to a 1.3-cm theoretical length of cut and ensiled. Tropical corn was harvested on approximately September 5 at one-half milcline. Tropical corn was harvested with a two-row forage harvester with a 1.3-cm theoretical length of cut and directly ensiled.

Crops were manually packed and ensiled in concrete stave silos 1.8 m in diameter × 1.5 m tall lined with plastic. Each forage was ensiled in three silos. Silage was manually packed into each silo. At silo filling, a representative sample was obtained from each silo by taking multiple grab samples from the forage as it was being conveyed into the silo. One-half of each sample was dried and analyzed for DM, CP, ADF, NDF, and soluble CP to determine initial quality. The other half of each sample was frozen at -20°C until analyzed for water-soluble carbohydrates (WSC). Two polyester bags (0.15-cm average mesh size, each containing approximately 1.0 kg of forage) were placed in each silo to provide a measure of ensiling losses. One was placed in the top one-third of the silo and the other was placed in the bottom one-third. As these bags were recovered during the feeding trial, they were transported to the laboratory for analysis and processing. Two hundred grams of ensiled forage was removed from the bag and dried at 55°C in a forced-air oven to determine DM and analyzed for NDF, ADF, CP, and soluble CP. A second 25-g portion was removed and diluted 10:1 with dis-

tilled water, blended for 1 min, and filtered through cheesecloth before measuring pH. Extracts were then centrifuged at  $10,500 \times g$  to remove the particulate fraction, stabilized with 25% metaphosphoric acid (1:5) and stored at  $-20^{\circ}\text{C}$  until assayed for organic acids (acetic, propionic, butyric, isobutyric, valeric, isovaleric, and lactic acids) via HPLC (Adams et al., 1984). The remainder of the sample was frozen at  $-20^{\circ}\text{C}$  until analysis of WSC.

### Animal Feeding

Holstein heifers (six per treatment) were individually fed each silage. Heifers ( $245 \pm 42$  kg in yr 1;  $155 \pm 20$  kg in yr 2) were placed in wooden metabolism pens ( $0.9 \times 3.5$  m) and offered experimental silages during an adaptation period (7 d in yr 1, 8 d in yr 2). Silages were offered at 0900 and 1600 h. Orts were collected before the 0900 feeding. Concentrate (0.45 kg of soybean meal for heifers fed tropical corn in yr 1 and all heifers in yr 2 or 0.45 kg of corn for heifers fed forage sorghum and pearl millet in yr 1) was fed immediately after Orts were collected, and silage was not offered until the heifers had consumed all concentrate.

After the adaptation period, heifers were offered 95% of their individual silage consumption based on the average consumption of the three highest days of the adaptation period in yr 1 or the last 3 d of the adaptation period during yr 2. Heifers were given 5 g of chromium oxide in their daily concentrate. Heifers were fed in this manner to allow equilibration of marker in the feces (5 d in yr 1 and 4 d in yr 2). Heifers continued to be fed in this manner for a 5-d collection period. Water and plain salt were offered ad libitum at all times. Fecal samples were collected daily during the collection period and dried at  $55^{\circ}\text{C}$  in a forced-air oven. A sample of each silage and concentrate was collected daily and frozen. At the end of the collection period, fecal samples were composited by animal using an equal amount of dry sample from each day. Silage samples were thawed at the end of the study and composited across the 5-d collection period using equal weights from each day and dried at  $55^{\circ}\text{C}$  in a forced-air oven. Samples of concentrate were analyzed individually to ensure that chromium intake was consistent across days. Chromium concentrations of daily feed samples were not different; therefore, values were averaged across days and used in all calculations.

### Sample Analysis

All dried samples were ground to pass a 1-mm screen in a Cyclotec sample mill (Perstorp Analytical, Silver Springs, MD). Crude protein was determined colorimet-

**Table 1.** Chemical composition of crops before and after ensiling.

	Forage sorghum	Pearl millet	Tropical corn	SEM
Preensiling				
DM, %	23.06 <sup>c</sup>	26.83 <sup>b</sup>	29.40 <sup>a</sup>	0.88
CP, % of DM	13.32 <sup>b</sup>	14.20 <sup>c</sup>	8.10 <sup>a</sup>	0.25
ADF, % of DM	38.02 <sup>a</sup>	37.70 <sup>a</sup>	33.43 <sup>b</sup>	0.48
NDF, % of DM	63.60 <sup>a</sup>	61.80 <sup>b</sup>	54.45 <sup>c</sup>	0.59
WSC <sup>1</sup> , % of DM	14.56 <sup>b</sup>	9.85 <sup>c</sup>	20.74 <sup>a</sup>	0.42
Soluble N, % of N	45.03 <sup>a</sup>	40.99 <sup>ab</sup>	36.13 <sup>b</sup>	1.90
Postensiling				
DM, %	21.97 <sup>c</sup>	26.34 <sup>b</sup>	30.48 <sup>a</sup>	0.63
CP, % of DM	12.90 <sup>b</sup>	14.36 <sup>a</sup>	8.25 <sup>c</sup>	0.18
ADF, % of DM	36.01 <sup>a</sup>	34.95 <sup>ab</sup>	32.94 <sup>b</sup>	0.79
NDF, % of DM	60.68 <sup>a</sup>	58.77 <sup>b</sup>	55.22 <sup>c</sup>	0.45
WSC <sup>1</sup> , % of DM	2.67 <sup>b</sup>	1.96 <sup>b</sup>	6.49 <sup>a</sup>	0.89
Soluble N, % of N	51.84 <sup>ab</sup>	52.84 <sup>a</sup>	49.43 <sup>b</sup>	1.06

<sup>a,b,c</sup>Values within a row without a common superscript differ ( $P < 0.05$ ).

<sup>1</sup>Water-soluble carbohydrate.

rically (AOAC, 1990). Neutral detergent fiber and ADF were measured using a filter bag technique (Vogel et al., 1999). Twenty grams of sodium sulfite and 4 ml of  $\alpha$ -amylase were added before starting the NDF procedure. Four milliliters of  $\alpha$ -amylase was added to the first and second rinse steps. Chromium in feed and fecal samples was determined by flame atomic absorption spectrophotometry (Perkin-Elmer 5000, Norwalk, CT) after digestion in a mixture of perchloric and nitric acid as described by Brown et al. (1989). The WSC were determined by the method of Dubois et al. (1956). Borate-phosphate soluble N was measured by the method of Krishnamoorthy et al. (1982). In vivo apparent DM, CP, NDF, and ADF digestibilities were calculated using the equations described in Cochran and Galyean (1994).

Data obtained from Dacron bags were averaged within each silo before they were analyzed using the GLM procedures of SAS (1985). The model included variation due to forage, year, and forage  $\times$  year interactions. Significant differences among forages were determined using Student's *t* test. Animal intake and digestion data were analyzed by analysis of variance using GLM procedures of SAS. This model included variation due to forage, year, and the interaction between forage and year, with initial BW of heifers used as a covariate. Differences among least square means were determined using Student's *t* test. Significance is at the  $P < 0.10$  level unless otherwise stated.

## RESULTS AND DISCUSSION

The chemical compositions of crops before ensiling are shown in Table 1. Tropical corn had the highest DM of all the forage crops, followed by pearl millet; forage sorghum had the lowest DM. However, DM was

less than 28% for forage sorghum and pearl millet. Silages with less than 28% are susceptible to clostridial fermentation, which can reduce silage quality (Edwards and McDonald, 1978). The low DM of preensiled forage sorghum and pearl millet indicates that the 24-h wilt time used in this study for forage sorghum and pearl millet may be inadequate to obtain optimal DM for silage production. However, increased wilt times would also increase the chance of additional field losses. Tropical corn harvested at the one-half milk line stage was also wetter than recommended for silage production and had a DM less than 30% (Table 1). Previously, Rakes et al. (1992) reported that tropical corn harvested at approximately one-half milk line contained 27% DM. Based on the data of Rakes et al. (1992) and this experiment, it appears that tropical corn harvested when grain is at optimum development may have low DM.

Tropical corn had the lowest concentrations of CP, NDF, and ADF (Table 1). Furthermore, tropical corn had the highest WSC concentrations. The relative differences between forage sorghum and pearl millet and tropical corn were expected and were primarily due to the grain development in tropical corn. Both pearl millet and forage sorghum were harvested while they were still in a vegetative stage, while tropical corn was not harvested until the grain was at one-half milk line.

Forage sorghum can be harvested after grain has started to develop, usually at the soft dough stage. However, McCormick et al. (1995) reported that vegetative forage sorghum produced higher quality silage than forage sorghum harvested following grain development. Likewise, pearl millet can also be harvested after grain development begins. However, previous work (Anonymous, 1961) has shown that silage made from pearl millet harvested in a vegetative stage was higher in quality than silage made from pearl millet harvested at the soft dough stage. Furthermore, cattle fed silage made from vegetative pearl millet consumed more DM, gained more weight, and produced more milk than cattle fed silage made from pearl millet harvested at the soft dough stage. Because the objective of this study was to harvest and compare silages made from crops harvested at optimal quality, both pearl millet and forage sorghum were harvested at a vegetative stage.

Volatile fatty acid concentrations and silage pH are shown in Table 2. During yr 1, some samples were destroyed during recovery. Samples out of one silo each of pearl millet and forage sorghum were destroyed. The bottom sample of a silo of tropical corn was also destroyed. Although tested, valeric acid was not detected in any of the silages made in yr 1 or 2.

Pearl millet silage had a final pH of greater than 4.2. A pH of less than 4.2 is indicative of well-preserved silage (McCullough, 1978). Silages with a pH greater

than 4.2, especially silages with less than 28% DM (Edwards and McDonald, 1978), are susceptible to putrefaction by clostridial fermentation. It does not appear that saccharolytic clostridial fermentation occurred in the silages in this study, because no butyrate—an end product of saccharolytic clostridial fermentation (Vetter and Von Glan, 1978)—was detected in any of the silages. However, isovaleric acid was greatest in pearl millet (Table 2). Isovaleric acid is formed during the deamination of leucine by clostridia (Vetter and Von Glan, 1978). Both pearl millet and forage sorghum had greater amounts of isobutyric acid than tropical corn silage. Deamination of valine results in the formation of isobutyric acid (Vetter and Von Glan, 1978). Furthermore, forage sorghum silage had a greater concentration of isovaleric acid than did tropical corn silage. These results suggest proteolytic fermentation by clostridia occurred to a greater extent in forage sorghum and pearl millet than in tropical corn silage. Furthermore, based on isovaleric acid concentrations, proteolytic fermentation may have been greater in pearl millet than in forage sorghum.

The relatively high pH of pearl millet silage can probably be attributed to the low preensiling WSC concentration in pearl millet (Table 1). This lack of substrate would likely limit microbial fermentation. Hill et al. (1999) reported that silage made from pearl millet cut at soft dough stage had high pH and low lactic acid concentration. This suggests that pearl millet WSC concentrations are lower than are adequate for ideal fermentation.

Silage made from tropical corn had a pH less than 4.0. Furthermore, tropical corn had the greatest concentration of WSC before ensiling as well as the greatest residual WSC after ensiling (Table 1), indicating that silage made from tropical corn was well preserved. Due to a scale malfunction, DM losses during ensiling were not measured during yr 1. However, DM losses were not different among forages in yr 2 and averaged 4.6% across forages.

**Table 2.** Organic acid concentrations and pH of silages.

	Forage sorghum	Pearl millet	Tropical corn	SEM
pH	4.09 <sup>b</sup>	4.50 <sup>a</sup>	3.96 <sup>b</sup>	0.06
Lactic acid, % of DM	5.61 <sup>a</sup>	3.33 <sup>c</sup>	4.42 <sup>b</sup>	0.32
Acetic acid, % of DM	6.78 <sup>a</sup>	3.97 <sup>b</sup>	3.93 <sup>b</sup>	0.41
Propionic acid, % of DM	2.05	2.11	2.15	0.17
Isobutyric acid, % of DM	3.92 <sup>a</sup>	3.82 <sup>a</sup>	1.49 <sup>b</sup>	0.50
Butyric acid, % of DM	nd <sup>1</sup>	nd	nd	
Isovaleric acid, % of DM	0.69 <sup>b</sup>	1.17 <sup>a</sup>	0.41 <sup>c</sup>	0.04

<sup>a,b,c</sup>Values within a row without a common superscript differ ( $P < .05$ ).

<sup>1</sup>Not detected.

**Table 3.** In vivo apparent digestibility of silages.

	Forage sorghum	Pearl millet	Tropical corn	SEM
DM intake, kg/d	3.95 <sup>b</sup>	4.92 <sup>a</sup>	3.88 <sup>b</sup>	0.14
Indigestible DM intake, kg/d	1.75 <sup>b</sup>	2.46 <sup>a</sup>	1.63 <sup>b</sup>	0.09
Digestible DM intake, kg/d	2.20	2.47	2.25	0.12
DM digestibility, %	56.83 <sup>a</sup>	51.36 <sup>b</sup>	58.13 <sup>a</sup>	1.47
ADF intake, kg/d	1.28 <sup>b</sup>	1.62 <sup>a</sup>	1.17 <sup>b</sup>	0.05
Indigestible ADF intake, kg/d	0.70 <sup>b</sup>	0.86 <sup>a</sup>	0.60 <sup>c</sup>	0.04
Digestible ADF intake, kg/d	0.58 <sup>b</sup>	0.76 <sup>a</sup>	0.57 <sup>b</sup>	0.04
ADF digestibility, %	47.14	47.81	48.92	1.85
NDF intake, kg/d	2.00 <sup>b</sup>	2.53 <sup>a</sup>	1.96 <sup>b</sup>	0.08
Indigestible NDF intake, kg/d	0.94 <sup>b</sup>	1.27 <sup>a</sup>	0.98 <sup>b</sup>	0.05
Digestible NDF intake, kg/d	1.06 <sup>b</sup>	1.25 <sup>a</sup>	0.98 <sup>b</sup>	0.07
NDF digestibility, %	53.80	50.70	50.37	1.81

<sup>a,b,c</sup>Values within a row without a common superscript differ ( $P < 0.05$ ).

Chemical composition of the crops after ensiling is shown in Table 1. Postensiling composition closely followed preensiling composition. Tropical corn had the greatest DM and lowest CP. In addition, ADF and NDF concentrations were lowest in tropical corn silage and highest in forage sorghum silage. Soluble N, as a percentage of total N, increased for all crops during ensiling. However, after ensiling, forage sorghum had the most soluble N, and tropical corn had the lowest amount of soluble N. Postensiled WSC followed the same patterns as preensiled WSC, except that there were no differences in the WSC concentration between forage sorghum and pearl millet.

To determine in vivo digestibility, each heifer was fed an amount of silage that would be consumed in a 24-h period so that they could not sort silage during intake. Many studies feed all animals as a percentage of BW or as percentage of ad libitum intake across treatment groups to eliminate the confounding of intake and digestibility data (Cochran and Gaylean, 1994). Because both intake and digestibility are related and both are important in determining usefulness and usability of a forage; controlling variation in forage intake could alter digestibility data, leading to different conclusions than those that would occur in on-farm production situations. Therefore, we fed each animal a percentage of its own previous intake.

Dry matter intake was greater for heifers fed pearl millet silage (Table 3). However, digestible DM intake was not different among the forages (Table 3). This would lead to increased storage and feeding costs if pearl millet silage was being used as a forage source and could lead to increased waste handling cost due to the increased indigestible DMI. Indigestible DM, NDF, and ADF intake were greatest for heifers being fed pearl millet silage (Table 3). This suggests that indigestible fiber and indigestible DM were not responsible

for the lower DMI for heifers being fed forage sorghum, and tropical corn.

Although heifers fed pearl millet silage consumed more DM, digestible DMI was similar among heifers fed all three silages. Because of the potential for increased storage and feeding costs associated with feeding more pearl millet silage to obtain similar digestible DMI, as well as the potential to make silage with a higher than optimal pH because of low preensiled WSC concentrations, pearl millet would not be a good candidate as a forage grown specifically for silage.

## CONCLUSIONS

Silage made from tropical corn was well preserved, as evidenced by low pH. Forage sorghum silage also had an acceptable pH. In vivo apparent digestibility of silage made from forage sorghum and tropical corn was similar in both years. Therefore, the decision of whether to use tropical corn or forage sorghum as a crop for silage production would be based on other factors, such as potential forage yield, economics, equipment needed for harvesting, and storing, and local disease and weather considerations rather than quality of silage produced.

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