

Fermentation characteristics and nutritive value of low moisture silage made from mature bermudagrass (*Cynodon dactylon*) and switchgrass (*Panicum virgatum*) in mixture with alfalfa (*Medicago sativa*) or treated with urea and plantain (*Musa AAB*)

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ABSTRACT

Two experiments were conducted at the University of Kentucky Spindletop Farm in Lexington, Kentucky, between October and November 2009 to evaluate the effect of different percentages of alfalfa (*Medicago sativa*) as mixtures in switchgrass (*Panicum virgatum*) and bermudagrass (*Cynodon dactylon*) silages, and also to investigate the effect of plantain and/or urea as additives in switchgrass and bermudagrass silages. Mini-silos of dimension 10.16 cm × 35.56 cm with PVC pipes and rubber caps on each end were used. In the first experiment, switchgrass and bermudagrass were ensiled separately in combination with four percentages of alfalfa (0%, 25%, 50% and 75 %) on fresh weight basis. In the second experiment, switchgrass and bermudagrass were ensiled with or without urea (6 or 12 g/ 6 kg of grass) and/or plantain (200 or 400 g/ 6 kg of grass) as additives. The alfalfa or additives were thoroughly mixed with the grasses and put in the micro-laboratory silos. Three replicates of the mini-silos were used for each treatment. After a 30-day fermentation, the laboratory silos were opened and sampled. Dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), and *in vitro* dry matter digestibility (IVDMD) were determined, in addition to fermentation characteristics of the silages such as pH, lactate, acetate, butyrate, glucose, and ethanol. The results indicated that increased alfalfa percentages in the mixture resulted in increased CP and digestibility of the switchgrass silage. The 25 per cent alfalfa inclusion for switchgrass, had significantly ($P \leq 0.05$) higher values for lactate contents compared to the other treatments. The 50 per cent alfalfa inclusion for switchgrass had the lowest pH (4.6). As alfalfa percentages increased from 0 per cent to 75 per cent, lactate content of bermudagrass silages was reduced from 5.4 to 1.6 mM. The lactate content was significantly ($P \leq 0.05$) higher for bermudagrass silage with 0 per cent and 25 per cent alfalfa. Bermudagrass silages were generally low in quality (pH above 5). The lactate contents of the bermudagrass were generally lower than that of the switchgrass in the second experiment. The urea + plantain combinations resulted in the highest lactate values and lowest pH values (4.2 – 4.4) for switchgrass. Switchgrass silage benefitted most from addition of alfalfa, urea and plantain. The silage quality of switchgrass could be improved with addition of 25 – 50 per cent alfalfa or addition of urea (6 or 12 g/6 kg grass) in combination with plantain (200 or 400 g /6 kg grass). The use of plantain alone as an additive can improve silage quality of bermudagrass, and legume can be mixed with switchgrass to enhance silage quality.

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Introduction

Silage making is practiced widely in intensive animal production systems in temperate regions, principally for winter feeding, and to provide high quality conserved feed all year round (t'Mannejte, 2000). In European countries, such as The Netherlands, Germany and Denmark, more than 90 per cent of the forages produced locally are stored as silage (Oude Elferink *et al.*, 2000). In the tropics, most of the grasses are known to have their highest nutritional value during the rainy season (t'Mannejte, 2000), and optimum harvest times often coincide with periods of excessive rains that restrict effective forage drying for hay production.

Silage making may be the most suitable fodder conservation method for the tropics because it is independent of weather conditions (McIroy, 1972). Silage preparation could, therefore, be one of the solutions to address the scarcity of good quality forage due to the severe and long dry season experienced in many parts of the tropics. Ajayi, Babayemi & Taiwo (2008), reported that if grass of any age is effectively managed, it can strategically be exploited to ameliorate forage scarcity in the off season and that, ensiling is a potent general method for forage preservation, and also a form of treatment to occasionally salvage the underutilised pastures for better acceptability and degradability. The ability of silage to improve cattle production has been demonstrated (Alan, 1993; Bolsen *et al.*, 1999).

Silage additives have been developed over the years to take some of the risk out

of the ensiling process, to improve the nutritive value of silages (Henderson, 1993), and to improve silage preservation by ensuring that lactic acid bacteria (LAB) dominate the fermentation phase (Titterton & Bareeba, 2000). Bolsen (1999) reported variable responses from silage additives, ranging from zero to highly significant improvements in silage quality and animal performance. Responses to additives, however, depend on what material or forage is being treated. It is possible to use both chemical and biological additives in making silage to promote adequate fermentation patterns, especially under sub-optimal conditions (Weingberg & Muck, 1996).

There are various options available in improving the nutrient concentration and utilisation of matured low quality grasses. A method agreeable to small-scale farmers is the incorporation of legume in grass/legume pastures or additions of legume to grass forage at feeding (Charmley, 2000). Titterton & Bareeba (2000) observed that mixing legumes with cereal crops and using silage additives are among several practices that contribute to improving the levels of fermentable carbohydrates, reducing buffering and preventing proteolysis to ensure good quality silage. Certain foodstuff such as plantain (*Musa aab*) when ripe produce fermentable sugars (Marriot, Robinson & Karikari, 1981), which could aid the ensiling process. The use of non-protein nitrogen, such as urea, as an additive to silage crops is mainly to reduce plant protein destruction during fermentation.

The use of certain chemicals as additives in silage making in West Africa, and in Ghana for that matter, dates back to the 1970's (Tuah, 1971; Larsen & Amaning-Kwarteng,

1976). Since then, some researchers have also tried to use other sources such as cocoa pod (Olubajo, Asonibare & Awulomate, 1989), poultry excreta (Oddoye, Okanta & Obese, 1996) and tomatoe pomace (Caluya 2000). Silage research conducted in Ghana has typically used grasses and cereals alone (Tuah, 1971; Fianu & Timpong-Jones, 2004; Okantah *et al.*, 2007) with little or no use of additives. The use of additives for silage making has still not caught up with most livestock farmers, and t'Mannetje (2000) suggested that addition of acids as silage additive may be beyond the resources of smallholders and can be dangerous too. Tropical grasses generally are inherently low in soluble carbohydrates (t'Mannejte, 2000), and mixing them with legumes in certain proportions will generally improve the quality of silage (Titterton & Bareeba, 2000).

The purpose of the study was to evaluate the effect of urea and plantain as additives for improving the quality of silages made with matured bermudagrass or switchgrass. The study also evaluated the effect on silage quality of different percentages of alfalfa in mixture with matured bermudagrass or switchgrass. Therefore, the specific objective of the study was to evaluate the mixing of matured grasses with either a legume or additives to enhance silage quality.

Materials and methods

The study was conducted at the University of Kentucky Spindletop farm in Lexington, KY between October and November, 2009. Forages used in the experiment were harvested from established stands of *Medicago sativa* (alfalfa; warm-season legume), *Panicum virgatus* (switchgrass; warm-season perennial grass) and *Cynodon dactylon* (bermuda-

grass; warm-season perennial grass). The plots had previously been left to fallow but all the current stands of forages were well established and about 2 years old. They had all been harvested once (previous year). The forages were harvested in late fall (October 20th, 2009), which coincided with the late growing season and, therefore, had matured. The switchgrass was harvested with garden shears and passed through a forage chopper which cut them into smaller pieces (about 5 – 10 cm long). The bermudagrass and alfalfa were harvested with a disc mower which gave a chopping length of about 2–3 cm. Different harvesting methods were used for the forages because of the differences in their physiology at the time of harvest.

Two experiments were conducted. In the first experiment, switchgrass and bermudagrass were ensiled separately, and each were in combination with four percentages of alfalfa (0%, 25%, 50% and 75% w/w) on fresh weight basis. The alfalfa was thoroughly mixed with the grasses and put in micro-laboratory silos of dimension 10.16 cm × 35.56 cm PVC pipes with rubber caps on each end. The silos were pressed with a hydraulic press to create anaerobic conditions and sealed immediately. Three replicates of the mini-silos were used for each treatment. In the second experiment, switchgrass and bermudagrass were ensiled with or without additives. The additives were urea (non-protein nitrogen) and ripe plantain (carbohydrate source). A blender was used to convert the plantain into a paste and added as either 200 or 400 g per 6 kg of grass. The urea also had two concentrations; 6 and 12 g per 6 kg of grass. The additives were thoroughly mixed with the grasses and placed into the micro-laboratory silos.

TABLE 1
The Nutritional Composition of the Forages Prior to Ensiling

| Forage type | DM | NDF | ADF | CP | IVDMD |
|--------------|---------------|------|------|------|-------|
| | ----- % ----- | | | | |
| Bermudagrass | 51.4 | 59.8 | 26.8 | 13.1 | 64.3 |
| Switchgrass | 42.9 | 67.4 | 36.4 | 8.1 | 49.9 |
| Alfalfa | 27.1 | 30.4 | 18.0 | 23.5 | 87.1 |

DM: Dry matter, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, CP: Crude protein, IVDMD: *In vitro* dry matter digestibility.

Chemical analysis

Harvested plant materials were sampled and dried in a forced-air oven at 60 °C for 48 h, and analysed to determine the initial nutrient composition of the forages. After a 30-day fermentation, the laboratory silos were opened and sampled after thorough mixing of material. Half of the sample was placed in a freezer (-20 °C) for estimating fermentation characteristics, and the remaining half was dried in an oven at 60 °C for 48 h. Dried samples were processed by grinding through a 1-mm screen using a Wiley Mill. Samples were analysed for N using a Leco FP-215 N Analyzer (Leco Corp., 300 Lakeview Av., St. Joseph, MI 49085) and converted to crude protein (CP = N% × 6.25). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the ANKOM 200 Fiber Analyser (ANKOM Technology, 2052 O'Neil Road, Macedon, NY 14502). Samples were analyzed for *in vitro* dry matter digestibility (IVDMD) by incubating in rumen fluid for 48 h in an ANKOM Daisey II Incubator. The silage samples stored in sealed plastic bags at -20 °C were processed for extraction. The extracts were made according to the method of Muck & O'Kiely (1992). The samples (10 g) were extracted in 100 ml deionized water. The fluid was filtered through two layers of cheesecloth,

and the filtrate clarified by centrifugation (25,000 × g, 25 min, 4 °C). The pH was determined at room temperature with a pH meter. Volatile fatty acid and sugar concentrations were determined by HPLC (Dionex, Sunnyvale, CA). The column (Aminex HP-87H, Bio-Rad, Hercules, CA) was operated at 50 °C, with a 0.4 ml min⁻¹ flow rate, and H₂SO₄ (0.17 N) mobile phase. A refractive index detector (Shodex/Showa Denko, Kanagawa, Japan) and a UV detector (Dionex, Sunnyvale, CA) were used simultaneously to detect eluting compounds.

Statistical analysis

All data were analysed using mixed models of SAS (Littell *et al.*, 1996). Nutritive values and fermentation characteristics of bermudagrass and switchgrass silages were analysed for effects of urea and plantain concentrations, and all interactions between the additives and grasses. Alfalfa percentages (0%, 25%, 50% and 75%) in mixtures with bermudagrass or switchgrass were evaluated as a continuous variable in determining linear effects on nutritive values. Grasses were evaluated in the models as discrete variables. Significant interaction ($P < 0.05$) between grasses and alfalfa percentages in mixture with the grasses was used as the test for heterogeneity of slopes.

All significant effects were determined at $\alpha = 0.05$ level of significance.

Results

The nutritional composition of the forages prior to ensiling is shown in Table 1. The DM ranged from 27.1 per cent in alfalfa to 51.4 per cent in the bermudagrass. Switchgrass had the highest NDF value (67.4%) whilst alfalfa had the lowest value (30.4%) with the value as low as half that of the switchgrass. This trend was similar for ADF. Crude protein ranged from 8.1 per cent in switchgrass to 23.5 per cent in alfalfa. The IVDMD was also highest in alfalfa followed by bermudagrass, with switchgrass having the lowest IVDMD of 49.9 per cent.

Table 2 shows the fermentation characteristics for bermudagrass and switchgrass silages, as affected by percentage of alfalfa (Experiment 1). The inclusion level of alfalfa did not significantly affect the pH, fructose, butyrate and ethanol levels of switchgrass. However, the 25 per cent inclusion level significantly increased the glucose and

lactate levels compared to the other treatments (Table 2).

Fig. 1 shows the linear relationship between percentage of alfalfa and pH changes of the mixture. The switchgrass - alfalfa silage mixture was generally of good quality with all the alfalfa inclusion levels in the mixture having a pH lower than 5.0. The highest pH (4.9) recorded was for the mixture with 75 per cent alfalfa whilst the mixture with 50 per cent alfalfa had the lowest pH of 4.6, even though there were no significant differences for pH among the switchgrass silage mixtures.

Bermudagrass silages were generally low in quality as indicated by the pH values which were generally above 5.0. The bermudagrass silage had a higher gradient compared to the switchgrass silage, which had a relatively gentle slope. There were higher variations in the pH of the bermudagrass mixtures as alfalfa percentages increased compared to the switchgrass (Fig.1). Generally, there was no significant difference between bermudagrass silages with 50 per

TABLE 2

Fermentation Characteristics for Bermudagrass and Switchgrass Silages Following 30-day Fermentation as Affected by Percentage of Alfalfa in Mixture with the Grasses

| Grass | Alfalfa | Glucose | Fructose | Lactate | Acetate | Butyrate | Ethanol |
|--------------|---------|--------------|----------|---------|---------|----------|---------|
| | |mM..... | | | | | |
| Bermudagrass | 0 | 2.0 a | 0 b | 5.4 a | 3.0 b | 0.7a | 2.7 b |
| | 25 | 1.4 a | 1.7 a | 4.5 a | 4.0 a | 0.5a | 5.7 a |
| | 50 | 0.6 b | 1.6 ab | 2.3 b | 1.3 c | 0.4a | 1.0 c |
| | 75 | 0.9 b | 1.8 a | 1.6 b | 1.3 c | 0.4a | 0.5 c |
| Switchgrass | 0 | 0 b | 0.5a | 0.3 c | 1.3 c | 0.1a | 3.3a |
| | 25 | 1.1 a | 1.6a | 4.0 a | 3.7 a | 0.1a | 1.7a |
| | 50 | 0.3 b | 0.9a | 2.4 b | 3.0 ab | 0.2a | 3.3a |
| | 75 | 0 b | 0.7a | 0.5 c | 2.7 b | 0.3a | 4.3a |

a,b,c Means within columns for each grass with different letters are significantly different, $P < 0.05$. Grasses were analysed separately.

cent and 75 per cent alfalfa inclusions for all the fermentation characteristics. The glucose and lactate contents of the silage were significantly higher for bermudagrass silage with 0 per cent and 25 per cent alfalfa compared to silages that had 50 per cent and 75 per cent alfalfa (Table 2). As alfalfa percentage increased in the mixture (from 0% to 75%), lactate content reduced from 5.4 to 1.6 mM (Table 2). Lactate content was highest (5.4 mM) in the bermudagrass only silage, but this was not significantly different from silages with 25 per cent alfalfa. The fructose contents were not significantly different among the different alfalfa percentages in the mixture. The treatment with no alfalfa, however, had no fructose. Butyrate content was not significantly different for bermudagrass among the treatments, and the butyrate contents were generally higher compared to the switchgrass silage. Due to the poor quality of bermudagrass-alfalfa silages, further nutrient analysis was not carried out on them.

Changes in percentages of alfalfa in switchgrass-alfalfa mixtures and subsequent changes in nutrient quality (IVDMD, CP, ADF and NDF) 30 days after ensiling are presented in Fig. 2. There was a curvilinear increase in IVDMD as alfalfa concentrations increased. The IVDMD increased by about 5 percentage units from sole grass silage to 25 per cent alfalfa inclusion. It, however, increased by about 11 percentage units from 25 per cent to 50 per cent alfalfa inclusion. The IVDMD also increased by about 18 percentage units from 50 per cent to 75 per cent alfalfa inclusion (Fig.2a), implying that as alfalfa inclusion levels increased, the per cent IVDMD also increased

Generally, the quality of switchgrass silage was better with higher CP and lowered NDF and ADF. Percentage CP increased linearly with increase in percentage of alfalfa and had a coefficient of determination $R^2 = 0.96$ (Fig. 2C). The CP content increased from 7.5 percentage units in the pure grass silage to 19 percentage units in silages with

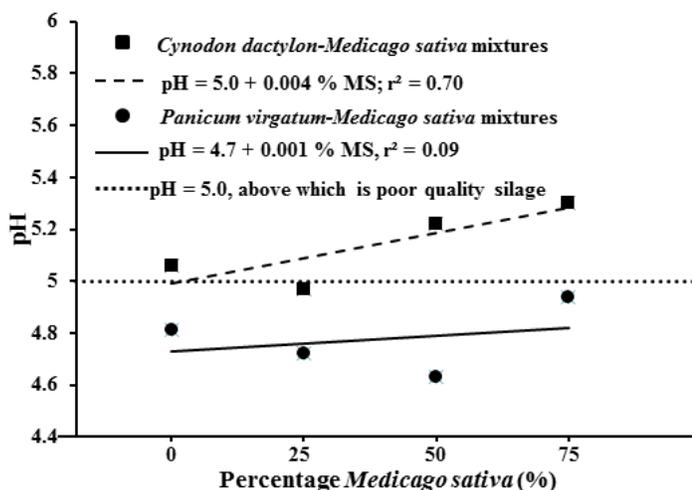


Fig. 1. Linear changes in pH with increased percentages of *Medicago sativa* (% MS) in silage mixtures with *Cynodon dactylon* and *Panicum virgatum* grasses.

75 per cent alfalfa inclusion. The NDF values of the silage mixtures had a negative linear relationship and decreased from no alfalfa to 75 per cent alfalfa inclusion with a coefficient of determination (R^2) being 0.97 (Fig. 2b). The proportionate declines with increases in alfalfa percentage indicated that adding alfalfa diluted the higher fiber of switchgrass. A similar trend was observed for the ADF except the coefficient of determination (R^2) which was 0.51.

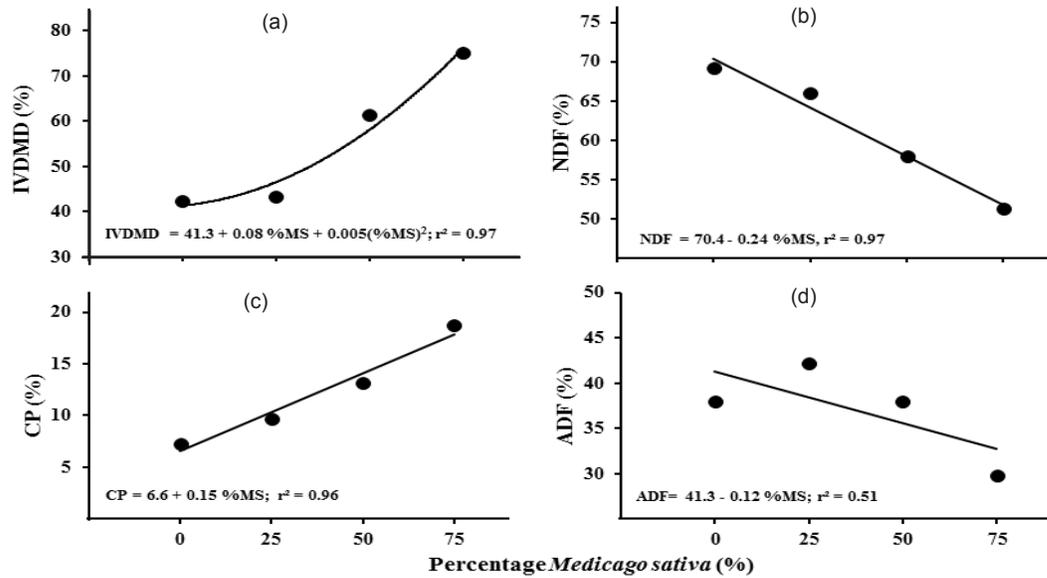


Fig. 2. Changes in percentages a) in-vitro dry matter digestibility (IVDMD), b) neutral detergent fibre (NDF), c) Crude Protein (CP), and d) Acid Detergent fiber (ADF).

Table 3 shows the fermentation characteristics (silage pH, lactate, acetate, butyrate, glucose, and ethanol) of bermudagrass and switchgrass silages, as influenced by two concentrations of both urea and plantain (Experiment 2). For switchgrass, treatments with no plantain had pH values that were not significantly different from each other, but they had higher pH compared to the other treatments. The plantain in combination with the urea as additive maintained low pH values as with the plantain additive only. Glucose contents were higher for treatments with 400 g of plantain/6 kg grass as part of the additives or as the sole additive. Glucose contents for treatments with 200 g plantain/6 kg grass had over six times less glucose than the plantain at 400 g/6 kg grass. Plantain at all levels in the treatments gave significantly higher fructose levels. Lactate was lowest in the no plantain treatments. The sole grass treatment had a lactate

level of 0.3 mM. This value increased three times when 12 g of urea/6 kg was added to the treatment (Table 3). Treatments with 400 g of plantain were not significantly different from each other in lactate levels, but had the highest lactate levels when 12 g of urea was added to the treatment. The urea + plantain combinations resulted in the highest lactate values and their pH was between 4.2 and 4.4. The observation was that the higher the urea concentration in the mixture, the higher the lactate value. Treatments with plantain were not significantly different for acetate, although plantain at 400 g/kg in combination with 6 g of urea/kg gave the highest acetate content of 4.0 mM.

Generally, the bermudagrass silages had higher pH compared to switchgrass silages (Table 3). The pH of bermudagrass without any additive was high (5.1), compared to the switchgrass without additive which had a pH of 4.8. The use of urea alone as additive at

TABLE 3

Fermentation Characteristics for Bermudagrass and Switchgrass Silages Following 30-day Fermentation as Affected by Urea and Plantain Additive Treatments

| Grass | Urea | Plantain | pH | Glucose | Fructose | Lactate | Acetate | Butyrate | Ethanol |
|--------------|--------------------------|----------|--------|----------------|----------|---------|---------|----------|---------|
| | -----g/kg fresh wt.----- | | | ----- mM ----- | | | | | |
| Bermudagrass | 0 | 0 | 5.1 c | 0.2 bc | 1.2 c | 0.2 d | 1.0 c | 0.3 | 16.0 a |
| | 0 | 200 | 4.9 d | 1.2 a | 3.2 b | 1.0 b | 3.0 ab | 0.2 | 7.7 b |
| | 0 | 400 | 4.7 cd | 1.2 a | 3.6 ab | 0.8 c | 2.7 abc | 0.2 | 5.3 b |
| | 6 | 0 | 7.1 b | 0.6 b | 1.8 c | 0.8 c | 2.0 bc | 0.5 | 3.3 c |
| | 6 | 200 | 5.8 c | 0.8 b | 3.5 ab | 1.4 b | 4.0 a | 0.3 | 5.3 b |
| | 6 | 400 | 5.7 c | 1.3 a | 4.2 ab | 1.6 ab | 4.0 a | 0.4 | 5.0 b |
| | 12 | 0 | 7.8 a | 0.4 c | 1.5 c | 0.5 c | 2.7 abc | 0.5 | 12.7 a |
| | 12 | 200 | 6.8 bc | 0.4 c | 1.7 c | 0.8 c | 3.0 ab | 0.2 | 3.3 c |
| | 12 | 400 | 5.8 c | 1.4 a | 4.7 a | 2.0 a | 4.3 a | 0.3 | 5.0 b |
| Switchgrass | 0 | 0 | 4.8 ab | 0 b | 0.5 b | 0.3 de | 1.3 c | 0.1 ab | 3.3 ab |
| | 0 | 200 | 4.4 b | 0.1 b | 3.0 a | 1.1 bc | 3.3 ab | 0.2 a | 4.3 ab |
| | 0 | 400 | 4.2 b | 1.1 a | 3.9 a | 1.2 bc | 2.7 abc | 0.1 ab | 1.3 c |
| | 6 | 0 | 6.3 a | 0 b | 0.7 b | 0.1 e | 2.7 abc | 0.3 a | 0.7 c |
| | 6 | 200 | 4.4 b | 0.2 b | 3.0 a | 1.4 abc | 2.7 abc | 0.1 ab | 1.7 c |
| | 6 | 400 | 4.3 b | 1.2 a | 3.9 a | 1.2 bc | 4.0 a | 0.1 ab | 3.0 ab |
| | 12 | 0 | 6.3 a | 0 b | 0.8 b | 0.9 cd | 2.0 bc | 0.2 a | 6.0 a |
| | 12 | 200 | 4.4 b | 0.2 b | 2.8 ab | 2.0 a | 3.0 ab | 0 b | 4.0 ab |
| | 12 | 400 | 4.2 b | 1.9 a | 4.9 a | 1.8 ab | 3.3 ab | 0.1 a | 2.7 bc |

a,b,c,d – Means within columns for each grass with different letters are significantly different ($P < 0.05$).

the treatment concentrations led to the highest pH values for both grasses (Table 3). The use of plantain alone as additive produced the lowest pH values for the bermudagrass. However, when urea was added to the plantain, the pH increased. The pH for the bermudagrass silages was generally above 5.0 and, therefore, considered to be of poor quality. The treatments with only plantain were not significantly different from each other, and had relatively lower pH of 4.9 and 4.7 for 200 and 400 g of plantain/6 kg grass, respectively (Table 3). All urea and plantain combinations had pH values that were not different from each other. Treatments with plantain alone were not significantly different from each other in terms of the glucose

content. Treatments with no plantain generally had significantly lower fructose content, whereas treatments with 400 g of plantain/6 kg grass had significantly higher fructose. The treatment with no additive had significantly lower lactate. The 12 g urea with 400 g plantain/6 kg grass provided the highest lactate (2.0 mM), even though this was not significantly different from combining 6 g urea with 400 g plantain/6 kg as an additive. All the treatments with plantain were not significantly different from each other in acetate content. Furthermore, the treatments without plantain were also not significantly different from each other in acetate content. The 12 g urea alone or in combination with 200 g plantain/6 kg grass was not signifi-

TABLE 4

Nutritive Composition for Bermudagrass and Switchgrass Silages Following 30-day Fermentation. Only Samples with pH < 5.0 were Analyzed

| Grass | Urea | Plantain | CP | IVDMD | NDF | ADF |
|--------------|------|----------|----------|---------------|--------|--------|
| | | | | ----- % ----- | | |
| Bermudagrass | 0 | 200 | 12.6 a | 61.0 | 55.9 | 29.6 |
| | 0 | 400 | 11.9 | 60.5 | 52.8 | 28.7 |
| Switchgrass | 0 | 0 | 7.3 c | 42.4 d | 69.2 a | 38.0 a |
| | 0 | 200 | 7.7 c | 47.7 c | 64.7 b | 36.7 b |
| | 0 | 400 | 6.9 c | 54.3 a | 57.9 d | 33.4 c |
| | 6 | 200 | 11.0 a b | 51.7 b | 64.9 b | 36.6 b |
| | 6 | 400 | 10.3 b | 54.4 a | 57.6 d | 32.7 c |
| | 12 | 200 | 12.4 a | 50.9 b | 63.2 b | 39.9 a |
| | 12 | 400 | 11.7 a b | 51.0 b | 60.6 c | 36.6 b |

a,b,c,d—Means within columns for each grass with different letters are significantly different, *P* < 0.05.

DM: Dry matter, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, CP: Crude protein, IVDMD: *In vitro* dry matter digestibility.

cantly different from each other for silage characteristics such as glucose, fructose, lactate, acetate and butyrate (Table 3).

The lactate content of the bermudagrass was lower than that of the switchgrass. On the other hand, butyrate content for the bermudagrass was higher compared to that of the switchgrass. The urea only treatments produced the highest butyrate for both grasses. Bermudagrass silages, generally, had higher ethanol compared to the switchgrass silages.

Table 4 shows the nutritive values for bermudagrass and switchgrass silages (with pH <5) with different levels of plantain and urea as additives. Most of the treatments for the bermudagrass silages were not of good quality, therefore, only treatment with sole plantain was analysed for nutritive value. With the exception of CP, the bermudagrass silage was not significantly different for plantain at 200 and 400 g/6 kg grass for IVDMD, NDF and ADF (Table 4). The treatment of

bermudagrass with only plantain as additive had higher CP values and better NDF and ADF compared to the switchgrass with only plantain as additive.

The switchgrass silage treatments that had plantain in combination with urea as an additive had significantly higher CP values compared to only plantain treatments and no additive treatments. The treatment with no additive had significantly lower IVDMD than the rest of the treatments. The NDF for all treatments with 200 g plantain/6 kg grass were not significantly different from each other (Table 4). The switchgrass silage without any additive had the highest (69.2%) NDF, and this was significantly higher than the other treatments. The plantain at 400 g + urea at 6 g/ 6 kg grass had the lowest NDF, but it was not significantly different from the treatment with only plantain at 400 g/6 kg grass. The treatment with 12 g urea and 200 g plantain/6 kg grass gave the highest ADF (39.9%), which was significantly different

from all the treatments except the treatment with no additive.

Discussion

The general observation that, as alfalfa levels increased in the silage, lactate content of bermudagrass silages lowered is an indication that the bermudagrass silage did not benefit much from alfalfa inclusion in terms of good silage fermentation. This is especially so because treatments without alfalfa had the highest lactate content of 5.4 mM. Schroeder (2004) observed that high quality silage is achieved when lactic acid is the predominant acid produced. Lactic acid is the most efficient fermentation acid because the pK_a is much lower than other typical fermentation acids. The switchgrass silage, on the other hand, had the highest lactate content with 25 per cent alfalfa, indicating that addition of alfalfa at that level could stimulate good fermentation in switchgrass. Silage quality seems to be related to lactic acid content according to Klosterman *et al.* (1960) (cited by Lopez, Preston & Sutherland, 1976). Low lactate content, therefore, indicates poor fermentation.

Most of the treatments for the bermudagrass silages were not of good quality, which was probably due to the relatively high initial DM content (51.4%). Staudacher, Pahlow & Honia (1999) observed that forages with DM content above 50 per cent (as observed for bermudagrass) were considered difficult to ensile. High DM content of an ensiled crop will reduce water activity to delay the decrease in pH caused by slow lactic acid bacteria growth rates (Weingberg & Muck, 1996). The amount of water soluble carbohydrate necessary to obtain sufficient fermentation depends on the DM content,

and the buffer capacity of the crop according to Oude Elferink *et al.* (2000). Even though the shorter chop length (2–3 cm) of the bermudagrass should have been an advantage for good fermentation, its high DM content restricted the fermentation (Schroeder, 2004). Dry matter content of the forage material to be ensiled is, therefore, critical in maintaining good fermentation. Generally, the switchgrass ensiled better probably because of its low DM (42.9%) compared to the bermudagrass. It is important to note that while the DM content of the bermudagrass silage was high by ensilage standards, it was typical for good quality haylage (Bernard *et al.*, 2010). However, the grass was prepared as silage (i.e. chopped and packed into a silo). Silages made with grasses that fall within the 40 – 60 per cent moisture brackets (as observed in the study), are also considered as low moisture silage (Cherney & Cherney, 2011).

The bermudagrass – alfalfa silages, with most of their pH values above 5.0, were classified as poor quality according to the pH limit of 5.0 set by Titterton *et al.* (2000). Weinberg & Muck (1996) also observed that after the fermentation phase of silage, the pH is usually between 3.8 – 5.0. Kung & Shaver (2001), however, disagree with this assertion, and indicated that a high pH due to restricted fermentation from high DM (> 45-50%) forages is not always indicative of poor fermentation or poor silage. They, however, observed that silage from a restricted fermentation is usually unstable when exposed to air because insufficient amounts of acid were produced to inhibit secondary microbial growth.

Increasing the proportion of alfalfa in the switchgrass silage elevated the CP concen-

tration of the silage (CP ranged from 6.6% at 25% alfalfa to 17.8% at 75% alfalfa; Fig. 2). The initial high CP of the alfalfa might have boosted the overall CP of the silage mixture and so the more the alfalfa inclusion, the higher the CP concentration in the silage mixture. Some studies (Titterton & Maasdorp, 1997; Mhere *et al.*, 1999; Kaplan, 2011) have shown that herbaceous legumes increase the CP concentration of silages. This is consistent with the observation that alfalfa addition improved both lactic acid production and IVDMD in switchgrass silages. It is likely that the addition of alfalfa simulated fermentation by both silage bacteria and rumen microorganisms by providing additional protein and other nutrients.

The NDF concentration of the switchgrass silage, which ranged from 58.3 per cent at 75 per cent alfalfa to 69.5 per cent at 25 per cent alfalfa inclusion, gives an indication that there was a decrease in NDF when the proportion of alfalfa was increased. Similar results were obtained in a moringa – elephant grass silage mixture (Mendieta-Araica *et al.*, 2009) in that increasing proportion of moringa in the silage mixture decreased the NDF. The observation in the study could be attributed to the relatively low concentration of NDF in the alfalfa (Table 1), which might have diluted the initial high NDF concentration of the switchgrass.

Although switchgrass silage with 75 per cent alfalfa had the highest CP value and a comparatively better ADF and NDF concentration, its relatively low lactic acid and high butyrate concentrations did not make it the best treatment in terms of silage quality.

Most of the treatments for the bermudagrass silages were not of good quality in terms of pH and butyrate concentration.

The high pH recorded for most of the bermudagrass silage treatments could be due to the comparatively low moisture (48.6%) of the bermudagrass before ensiling. Schroeder (2004) concluded that fermentation is restricted if the forage is too dry, and the pH cannot drop sufficiently. The bermudagrass treatment with sole plantain as treatments, however, had some good fermentation in terms of lowered pH. Matsuoka, Branda & Fujita (1997) observed among other reasons that the acidity of silage environment was one of the main reasons why hemicellulose was broken up in silage. This is probably why the lowered pH in the sole plantain treatments also produced lowered NDF (Table 4) compared to the initial NDF of bermudagrass (Table 1). The use of plantain alone as a carbohydrate source improved some fermentation indices, probably due to the ability of plantain to provide a substrate (soluble carbohydrate) to the LAB. Bermudagrass silage with plantain + urea additive, however, maintained a high pH.

The inclusion of plantain as additive for switchgrass improved the fermentation process and the silage quality as evidenced by the low pH, and increased lactate concentration of the resultant switchgrass silages. Skerman (1989) observed that the quality of silage could be determined by the amount of sugar in the ensiled material, and recommended that the sugar must be high enough to give a quick fermentation. The high levels of glucose and fructose (Table 5) in the plantain, therefore, apparently enhanced the fermentation. Using a carbohydrate source as additive for grass silages helps to increase the supply of substrate for the lactic acid bacteria which aid the fermentation process (Henderson, 1993). This is likely why

TABLE 5

NDB No: 9447 (Nutrient values and weights are for edible portion of ripe plantain)

| Nutrient | Units | Value Per 100 grams |
|-----------------------------|-------|---------------------|
| Proximates | | |
| Water | G | 49.04 |
| Energy | kcal | 236 |
| Energy | kJ | 989 |
| Protein | G | 1.42 |
| Ash | G | 1.26 |
| Carbohydrate, by difference | G | 40.77 |
| Fiber, total dietary | G | 3.2 |
| Glucose (dextrose) | G | 4.97 |
| Fructose | G | 4.86 |
| Lactose | G | 0.00 |

Source: USDA National Nutrient Database for Standard

lactate levels were highest in silages with plantain.

The urea only treatments produced high pH and butyrate, which is indicative of poor quality silages. Muhlbach (2000) made a similar observation and concluded that generally, pH value, ammonia-N and butyric acid contents are increased with urea additives. Lavezzo (1993) cited by Muhlbach (2000) reviewed the use of urea as silage additive for elephant grass and concluded that with low-DM forage and in the absence of additives rich in water soluble carbohydrate, urea may not be the best additive when improvement of fermentation is the aim. On the other hand, when urea was combined with plantain as additive for switchgrass silages, the pH was lowered probably because the plantain functioning as a substrate for the LAB maximised the fermentation processes.

Using urea as an additive has been observed to increase the crude protein content of silage (Oude Elferink, 2000) and could

contribute to aerobic stability of the silage (MacDonald, Henderson & Heron, 1991). In the study, however, even though the urea improved the CP of switchgrass silage, using urea alone produced poor quality silage with their pH above 6.0 (Table 3). Crude protein increased significantly when urea was added to plantain as additive in switchgrass. The urea, therefore, boosted the effectiveness of plantain as an additive. Urea and plantain when used together could boost nutrient content, and also improve fermentation of silages prepared from matured grasses. More research is, however, needed in this direction. Although the switchgrass initially had low CP, there was a significant increase in CP after inclusion of additives (urea + plantain combined). The combination also resulted in relatively high lactate levels and lowered pH. These observations suggest that fermentation was better by combining these additives. The NDF for the switchgrass silage without any additive was high indicating high fibre content. When the additives were introduced, the NDF reduced suggesting that the quality of switchgrass silage improved with the introduction of the additives. The additives probably aided the breakdown of the total plant fibre of the grass resulting in lowered NDF.

Conclusion and recommendations

In the study, low quality forage (switchgrass) benefitted most from the addition of alfalfa, urea and plantain. The benefits from alfalfa was in terms of increased CP, lowered NDF and ADF, but to ensure good quality silage in terms of lactic acid production and good pH, the alfalfa inclusion levels should be between 25 per cent to 50 per cent. The use of plantain (carbohydrate source) as additive

in combination with urea improved the nutritional value and fermentation characteristics of switchgrass and should be exploited.

Generally, silages made from matured bermudagrass in mixtures with alfalfa (0%, 25%, 50%, 75%) did not produce good fermentation. The use of plantain alone as additive for bermudagrass at both 200 and 400 g per 6 kg grass is recommended. The use of urea (6g/6 kg of grass and 12g/6 kg of grass) alone is not recommended as additive for both bermudagrass and switchgrass silages when the grasses are matured.

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