ROUND BALE SILAGE - A FORAGE HARVESTING ALTERNATIVE

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SUMMARY

This report summarizes the results of 5 years of multi-disciplinary research conducted by the Institute of Food and Agricultural Sciences, University of Florida on the conservation of forages as round bale silage. Grasses and legumes have been harvested using conventional hay making equipment and ensiled as large, round bales of high moisture forage sealed in plastic. When compared to hay, round bale silage offers an alternative forage conservation system that decreases the amount of time spent drying the forage prior to storage. The benefits of this system include reduced rain damage and field losses, and increased flexibility in scheduling harvesting (allowing producers to harvest for optimum forage quality and yield). When compared with chopped silage, the benefits of round bale silage include excellent dry matter recovery, decreased energy costs and lowered initial capital investment. Main disadvantages are increased capital investment and costs for expendable supplies (when the system is compared to hay), and the susceptibility of plastic used to store round bale silage to rodent damage and deterioration under intense sunlight. Field wilting (to increase dry matter at time of storage to 40 to 50%) improves the quality of round bale silage made under Florida conditions. Three to four hours usually is required to accomplish this degree of wilt with bermudagrass. Adding ammonia to round bale silage prevents external molding but may result in undesirable fermentation characteristics, especially when high moisture, tropical forages are ensiled. Microbial inoculation (to promote lactic acid production) temporarily improves the quality of direct-cut, high moisture (<30% dry matter) round bale silage made with bermudagrass, but pH of inoculated silage generally is not lowered enough to stabilize such silage in a high-quality state. The combination of cellulase-enzyme treatment and inoculation, however, has shown potential to improve the quality of bermudagrass round bale silage.

INTRODUCTION

Seasonal variation of forage quality and quantity is a major problem affecting livestock production in Florida (Moore, 1979). Many livestock producers attempt to alleviate low winter forage production by harvesting forage during periods of peak production and conserving it for use during the winter. However, a problem in much of the southeastern United States is the inability to make high quality hay without rain damage. Based on 50 years of data collected by the Agronomy Department, University of Florida, the lowest probabilities of encountering a 3-day dry period with conditions suitable for making hay in north Florida are from the middle of June through the end of August, a time of rapid forage growth (Figure 1). Rain delayed harvest of forage presents a problem because of the rapid decline in forage quality that is observed with most tropical forages (Moore, 1979).

Recently, the concept of round bale silage has attracted increased attention as an alternative harvesting method because of the greater flexibility it affords with regard to time of harvest (Henderson, 1987). Many producers who have equipment on their farms to produce hay can harvest high moisture forage as large round bales and seal them in plastic (Anderson et al., 1984). The resulting round bale silage can be handled and fed in a fashion similar to round bale hay.

Although limited research has been conducted on the ensiling of tropical forages, the Florida Agricultural Experiment Station was a leader in conducting early research on this conservation method (Becker et al., 1970). In much of this earlier research, low dry matter (DM) intakes were associated with tropical grass and legume silages. An analysis of many of the earlier experiments, however, indicated that silage intake was related to DM content of the original forage. Direct cut silages tended to spoil and were associated with decreased DM consumption. Wilting pangola grass increased DM from 18.8% (direct-cut) to 32.2% and increased DM intake from 1.12% to 1.87% when expressed as a per cent of body weight (Wing and Becker, 1963).

This report attempts to summarize our experience with round bale silage. Much of our research has looked at the influence of field wilting on the effectiveness of this alternative method of harvesting and storing forage. The effects of additives such as ammonia, microbial inoculants and cellulase-enzymes also have been determined. Most of our research has been conducted with bermudagrass and rhizoma peanut, but we believe that the results are similar to those that would be experienced if round bale silage was made with other forages grown in Florida.

HARVESTING

We used conventional hay making equipment to make round bale silage for our research. Forage was cut and mechanically conditioned using a New Holland model 489 haybine. Although most newer balers will roll high moisture bales without difficulty, we initially used a New Holland model 855 baler to make 5' wide bales, but a model 848 baler was used in subsequent years to make 4' wide bales. The larger bales were heavier (up to 2200 lb) than our front end loader could easily and safely handle. Currently, we make bales that are approximately 4' wide and 4 1/2' in diameter. The weights from over 200 bales of this size ranged from

1300 to 1800 lb depending on forage DM (Table 1).

Increasing forage DM (by field wilting) resulted in lower bale weights, but more DM/bale; at 50% DM the dry weight/bale approached that of hay bales that were of similar size made with the same machine. The density of round bale silage, however, has been considerably less than that expected for chopped silage made with comparable forage and stored in bunker or upright silos (30-40 lb/cu ft).

Baling round bale silage takes approximately as long as it takes to make hay. The forage pick-up time in our research (which frequently involved spraying an additive onto the forage during baling) averaged 1.5 to 2 min/bale, but has been as low as 1 min/bale.

STORAGE

Although most of our research was conducted with high moisture round bales stored in plastic, several different plastic storage systems have been used including stacks of bales covered with sheets of plastic, individual bale bags, long tubes of plastic and bales wrapped with stretch plastic. Storage under a large sheet of plastic was useful only when large numbers of cattle were fed the stored forage. Otherwise, spoilage rapidly affected the remaining un-fed bales left after the plastic was removed. Similarly, damage to the plastic sheet resulted in the spoilage of many bales.

Indeed, the single most important factor affecting the success of round bale ensiling is the ability of the plastic covering the high moisture bales to effectively exclude air. The quality of round bale silage is dependent on excluding air from the bale storage system. We have encountered frequent difficulties with rodent damage and ultraviolet deterioration (due to sunlight) of the plastic used in every round bale silage storage system we have looked at to date. It is imperative that high-quality plastic with sufficient thickness and ultraviolet light inhibitor be purchased. Ask the salesman for specifications if there is any doubt about the ability of the plastic to withstand long periods of intense Florida sunshine. Also, plastic must be checked periodically during bale storage and holes repaired with plastic tape.

During the first 2 years of our research we used individual bale bags, but later switched to tubes which could store a number of bales because of the higher cost and labor requirements of the first system (Table 2). More recently, we have used a stretch-wrap system in which each bale is machine wrapped with flexible polyethylene. Cost of the polyethylene in this later system is approximately $3.00/bale. Each bale is wrapped with four to five layers of polyethylene that is 1 mil thick. Two or two and one-half minutes are required to wrap a bale. The wrap system is our system of choice even though costs are somewhat higher than for the tube system (Table 2). Our reason for choosing the wrap system is that the tight wrap excludes much more air than any of the other systems which were used previously in our research. In addition, holes in the stretch wrap result in less spoilage than holes in plastic bags or tubes.

EFFECT OF FORAGE DRY MATTER AT TIME OF STORAGE

Most forages that are used by cattlemen in Florida contain little fermentable carbohydrate to fuel the ensiling fermentation (ie., bermudagrass contains 2 to 3% water soluble carbohydrate on DM basis). A high buffering capacity (which resists decline in forage pH during ensiling) also is characteristic of forages in Florida (ie., approximately 5.5 lb lactic acid are required to lower the pH of a water extract of 100 lbs dried bermudagrass from pH 6.0 to pH 4.0). These attributes are similar to those of alfalfa, a forage that many dairy farmers in the midwest ensile and rely on as their predominant source of forage. Dairy farmers in that part of the U.S. have found that field wilting to increase forage dry matter at time of ensiling to 40 or 50% DM improves the quality of alfalfa haylage. The sugar:buffering capacity ratio of bermudagrass is less than 1.0 and is in the range thought to be indicative of forage that is difficult to ensile in a high moisture state (Figure 2; Woolford, 1984). Field wilting bermudagrass to 40 to 50% DM also improves the quality of bermudagrass silage (see Bates et al., 1985 and 1989).

Many of our studies were conducted with relatively immature bermudagrass (5 to 6 weeks regrowth following the previous cutting). Unwilted bermudagrass of 5 to 6 weeks regrowth ensiled directly after harvest typically has a DM content of 23 to 28%. Three to four hours of field wilting during mid-day often will raise the DM of this forage to 40 to 50%. Alternatively, the producer can harvest this forage in the late afternoon and wilt over night to achieve a similar increase in forage DM. The DM content of more mature bermudagrass is higher than that found in comparable immature forage (ie., the DM of direct-cut bermudagrass at 8 weeks regrowth was over 40% in one study and approximately 35% in others). The DM of mature rhizoma peanut, however, is less than 30%.

Field wilting which increases DM of ensiled forage to 40 to 50% restricts the activity of microbes carrying out the silage fermentation. The pH of wilted silage often is higher than pH 6.0. Butyric acid and ammonia (which indicate spoilage), however, usually are lower in wilted silage and overall quality is improved (Bates et al., 1989). The dry matter recovery of wilted bermudagrass round bale silage (40 to 50% DM) is 10 to 15% higher than that of silage made with the same, non-wilted, forage. In some years, immediate improvement in dry matter recovery was observed when direct-cut silage (<30% DM) was field wilted, even if for short periods of time (ie., 1 to 2 h to a DM of approximately 35%; Bates et al., 1989). In other years, the most dramatic improvement in dry matter recovery was observed when bermudagrass was dried sufficiently to raise forage DM to greater than 35% (Figure 3A).

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[1]Medipharm, USA.

Cattle also eat more bermudagrass round bale silage when it has been field wilted. This has been observed in studies conducted in two separate years. In 1986, the linear and quadratic effects of forage DM (%) within treatment (control, ammonia, inoculant, cellulase-enzyme, and cellulase-enzyme plus inoculant) on voluntary dry matter consumption (in lb, by cattle weighing 500 lb) did not differ. The overall effect of forage DM on intake was significant ($p<.01$; n = 98) and described by the following linear equation: $5.58 + .095X$ ($r^2=.56$). In 1987, the linear and quadratic effects of forage DM within treatment were different (p=.0031 and p=.0073, respectively). Individual regressions of voluntary dry matter consumption on forage DM are plotted for each treatment in Figure 3B. The regression of consumption on forage DM in the 1987 study (across all treatments, pens and periods) was $-17.73 + 1.333X - .016X^2$ (n=110, $r^2=.67$). Most importantly, wilted bermudagrass round bale silage supported higher rates of gain and growth of heifers (Table 3).

Although the gains achieved with wilted, non-treated bermudagrass round bale silage were less than those observed with hay fed cattle, the likelihood exists that certain silage additives may provide additional increases in cattle performance (Figure 3B). Subsequently, in addition to our emphasis on field wilting, we are directing continuing efforts toward assessing the effect of silage additives on the quality of round bale silage made with forages used by Florida cattlemen.

ADDITIVES

Microbial Inoculants

Catchpoole (1970) and Catchpoole and Williams (1969) reported that, unlike silage made in temperate regions, silage made under subtropical conditions is characterized by high concentrations of acetic as well as lactic acid. Similar results were found by researchers in the Caribbean basin (Xande, 1978; Tosi et al., 1975). McCullough (1978) summarized data which indicated that the warm and humid environment of the southeastern U.S. creates poor ensiling conditions which foster proliferation of clostridia and other undesirable silage microorganisms. Also, acetic acid is not as strong an acid as lactic acid, and its accumulation actually buffers against a decline in silage pH below 4.8.

Wilkens et al. (1971) studied the relationship between silage composition and intake. They reported a negative correlation (r=-.77) between acetic acid concentration and voluntary dry matter intake when grass silage was fed to sheep. Hamilton et al. (1978) theorized that a substantial decline in DM and digestibility of ensiled subtropical silage was due to extensive gaseous loss of the fermentable portion

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[2]American Farm Products
[3]Fermco Development Inc., a subsidiary of Finnsugar
[4]Flieg scores are correlated with intake; high Flieg scores reflect good silage quality. This system rewards silage that has a high concentration of lactic acid, but discounts silage with high concentrations of acetic or butyric acids.

of the forage DM during an acetic acid fermentation. Much of the round bale silage that we have studied has been characterized by relatively high concentrations of acetic acid in relation to lactic acid. Thus, an objective of our research has been to study the
effect of inoculating round bale silage with lactic acid producing bacteria.

Epiphytic (initial) lactobacilli counts in non-inoculated, direct-cut bermudagrass round bale silage averaged 10^4/g forage DM. Three species of lactic acid producing bacteria, Pediococus acidilactici, Lactobacillus plantarum and Streptococcus faecium, were obtained commercially[1]
and grown in batch culture. This culture was sprayed onto the forage as the bales were rolled, raising the lactobacilli counts to 10^6/g forage DM. Inoculation was effective in increasing the participation of lactobacilli in the silage fermentation (Figure 4A), causing a rapid decline in pH to values lower than those associated with control silage (Figure 4B) and higher lactic acid concentrations [.82 and 1.32% (DM basis) for control and inoculated bales, respectively]. Microbial inoculation temporarily improved the quality of direct cut bermudagrass round bale silage, but pH of the inoculated silage did not decline sufficiently to prevent secondary spoilage from occurring (Figure 5A and B). Dry matter recovery was improved in 2 of the 4 years that inoculants were studied, with most of the improvement seen with high moisture, direct cut silage (ie., Figure 3A; also, see Bates et al., 1985). Inoculation, however, did not significantly affect dry matter intake by growing heifers (500 lb body weight) in either of 2 years [9.4 ± .6 vs 10.0 ± .7 lb/hd/d in 1986 (across forage DM ranging from 25 to 50%); and 9.9 ± .7 vs 10.8 ± .6 lb/hd/d in 1987 for control and inoculated bales, respectively (see Figure 3B)].

Cellulase-Enzyme and Inoculant

Mixed enzyme preparations containing cellulase were obtained from two commercial sources[2,3] and tested for their ability to increase the extent of fermentation in inoculated round bale silage. Two levels of inoculant were tested, 10^5 and 10^6 lactobacilli/g forage DM. Solutions containing the inoculant and enzymes were sprayed onto the forage as bales were formed. Cellulase-enzyme treatment resulted in a more extensive silage fermentation as characterized by increased concentrations of lactic and acetic acids, and a somewhat lower pH than inoculated round bale silage (Table 4). The enzyme treatments also significantly decreased the number of yeasts and molds found in bermudagrass round bale silage after more than 3 months of storage, but increased total anaerobes (Figure 6). Although Flieg score[4] was not affected (Table 4), one of the enzyme treatments (referred to as Enzyme 1 in Table 4) increased dry matter recovery (of wilted silage, Figure 3A) and dry matter intake (across the range of forage DM from 25 to 50%, Figure 3B). Enzyme 1 increased dry matter recovery from a mean of 89.7 to 97.9%, and dry matter intake of 500 lb heifers from a mean of 10.1 to 12.6 lb/hd/d (an increase of 25%). Enzyme 2 was not tested for its effect on dry matter recovery or intake. Both levels of microbial inoculant were equally effective in promoting the silage fermentation when used in conjunction with a cellulase-enzyme treatment.

Ammonia

Ammoniation of high moisture hay reduces the growth of yeasts and molds, and decreases the rate of aerobic deterioration (Thorlacius and Robertson, 1984; Woolford and Tetlow, 1984). We have observed a substantial reduction of external molding when ammonia was metered into the sealed plastic container of round bale silage at the rate of 6 to 7 lb/bale (Bates et al., 1985 and 1989). This level of ammonia also increased the crude protein of the treated forage in one year's study (Bates et al., 1989). Higher application rates have been shown to increase the digestibility of low quality forage (Brown et al., 1987).

Unfortunately, ammoniation is associated with undesirable fermentation characteristics, especially when direct-cut low DM tropical forages are ensiled. Dry matter recovery and intake of ammoniated, direct-cut, bermudagrass round bale silage was very poor (Figure 3A and B). Although application of ammonia to bermudagrass wilted to 40 to 50% DM improved the quality of round bale silage (Figure 3A and B), we do not recommend this practice because of the high level of management required for success, and because treatment of silage and hay with ammonia has, on occasion, been toxic to cattle.

CONCLUSIONS

1. Ensiling forage as high moisture round bales provides an alternative forage harvesting-storage system to making hay that decreases the amount of time spent drying the forage prior to storage. The primary advantage of round bale silage is the greater flexibility that this system affords with regard to time of harvest.

2. Wilting bermudagrass to 50% DM increases (by approximately 25%) the amount of round bale silage that is voluntarily consumed by cattle as compared to direct-cut silage. Dry matter recovery and cattle gains also are improved by this management technique.

3. Inoculating bermudagrass round bale silage with lactic acid producing bacteria temporarily improves silage quality, but the terminal pH of inoculated bermudagrass silage in our studies has not decreased sufficiently to prevent secondary spoilage.

4. Treatment of bermudagrass round bale silage with a combination of enzymes containing cellulase (to convert structural carbohydrate of the plant cell wall to fermentable water soluble carbohydrate) and microbial

inoculant, however, showed potential to improve bermudagrass silage quality as gauged by willingness of cattle to eat the silage. Increased dry matter recovery also was observed with cellulase-enzyme treatment, provided the forage was field wilted prior to storage.

5. Although ammonia treatment improved the dry matter recovery and voluntary consumption of wilted bermudagrass round bale silage (40-50% DM) by cattle, this additive was detrimental when added to high moisture, direct-cut bermudagrass round bale silage.

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Table 1. BALE WEIGHTS AND DENSITY OF ROUND BALE SILAGE[a,b]

Category			
Wilt Time, hr. :	None	1-2	3-4
Forage Dry Matter,% :	23-28	35-40	45-50
Bale Weight, lb			
Range	1400-1800	1350-1700	1300-1600
Average	1650	1550	1450
Bale Dry Matter, lb			
Range	400-550	500-650	650-750
Average	475	600	700
Bale Density, lb/cu.ft.[c]			
Wet Forage	26.0	24.4	22.8
Dry Matter	7.5	9.4	11.0

[a]Adapted from Kunkle et al., 1988; summary of 200 bales over 2 years.
[b]New Holland 848 baler used to make bales 4' wide and 4 1/2' diameter using bermudagrass (5-6 week regrowth).
[c]Calculated using 63.6 cu.ft./bale.

Table 2. ESTIMATED COSTS OF ROUND BALE SILAGE STORAGE SYSTEMS[a,b]

	Storage System		
Cost Category	Bale Bag	Long Tube	Stretch Wrap
Storage Equipment			
Investment, $	---	3100 (stuffer)	7800 (wrapper)
Cost/Bale, $[c]	---	1.05	2.60
Polyethylene, $/Bale	7.50	3.10	3.00
Labor			
No. Men	3	2	2
Bales/hr	15	20	15
$/Bale[d]	1.20	.60	.80
Total Cost			
$/Bale	8.70	4.75	6.40
$/Ton DM[e]	29.00	15.80	21.30

[a]Adapted from Kunkle et al., 1988.
[b]Estimated costs based on our experiences and 1988 prices, cost of moving equipment, tractor costs to operate bale stuffer or wrapper not included.
[c]Equipment depreciated over 3000 bales.
[d]Labor cost calculated at $6.00/hour.
[e]Bale estimated to contain 600 lb of dry matter (DM).

Table 3. PERFORMANCE OF GROWING HEIFERS FED BERMUDAGRASS ROUND BALE SILAGE OR HAY, 1988[d,e]

	Forage dry matter, %				
Performance trait	25-30	35-40	45-50	90-95 (hay)	SE
ADG, Full weight[f]	- .36[a]	.21[b]	.38[b]	.62[b]	.15
ADG, Shrunk weight[g]	- .17[a]	.12[a,b]	.27[b,c]	.65[c]	.11
Change in height[h]	.33[a]	.67[b]	.74[b]	.93[b]	.08
Change in condition score[i]	-1.95	-1.50	-1.15	-1.11	.07

[a,b,c] Means without a common superscript differ (P<.05).
[d]Crossbred heifers averaging 500 lbs body weight; two pens with ten heifers apiece were assigned to each treatment.
[e]Bermudagrass used in this trial was 6 weeks regrowth and contained 10.1% crude protein (DM basis) and had an in vitro organic matter digestibility of 48.9%.
[f]Average daily gain (lb) measured full weight to full weight over a 76d feeding period.
[g]Average daily gain (lb) measured shrunk weight to shrunk weight over an 88d feeding period.
[h]Change in height (in) at hooks over an 88 d feeding period.
[i]Visually evaluated change in condition over an 88 d feeding period; change in condition score of -1 indicates an estimated loss of condition equal to 1 mm.

Table 4. EFFECT OF CELLULASE-ENZYME TREATMENT ON THE FERMENTATION OF DIRECT-CUT (<30% DM), BERMUDAGRASS ROUND BALE SILAGE.[a]

		Silage Characteristics				
Enzyme treatment	Added inoculant[b]	pH	Lactate, % DM	Acetate, % DM	Butyrate, % DM	Flieg score
None	None	5.10	.83	.69	.38	18.3
None	10^6	4.59	1.32	.82	.27	36.3
Enzyme 1[c]	10^5	4.31	1.10	1.56	.31	17.7
Enzyme 1	10^6	4.16	1.31	1.77	.22	23.0
Enzyme 2[d]	10^5	4.31	1.72	2.41	.25	21.3
Enzyme 2	10^6	4.40	2.17	2.78	.29	23.3
SE[e]		.12	.26	.33	.10	7.8

[a]Bermudagrass was 5 to 6 weeks regrowth.
[b]Number of inoculant organisms added/g forage DM.
[c]Clampzyme[TM], Fermco Development Inc.
[d]Silage Pro[TM], American Farm Products.
[e]Standard error of the mean.

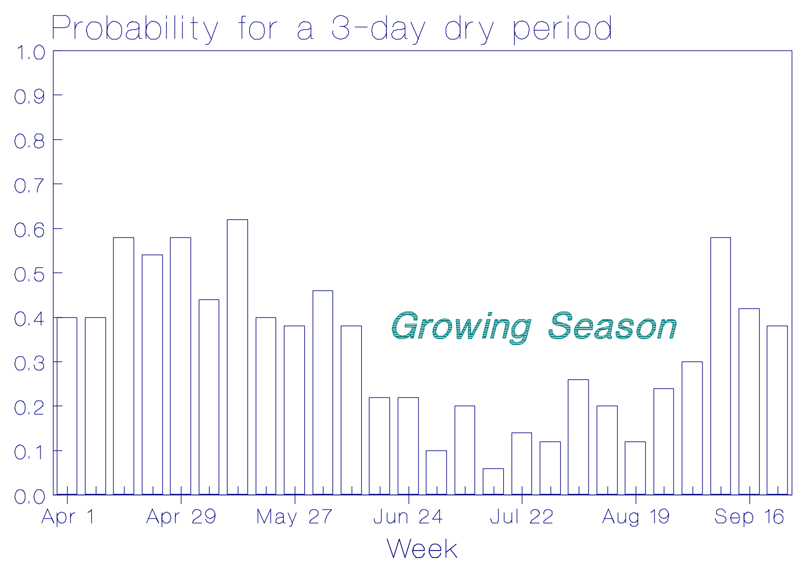


Figure 1. Probability of 3 consecutive dry days out of each week during the spring and summer in north Florida; data collected by the Agronomy Department, Univ. of Florida.

Figure 2. Forage dry matter required for good quality silage as affected by sugar: buffering capacity ratio (adapted from Woolford, 1984). The low sugar: buffering capacity ratio of bermudagrass indicates the need to wilt this forage to a dry matter greater than 40% prior to ensiling.

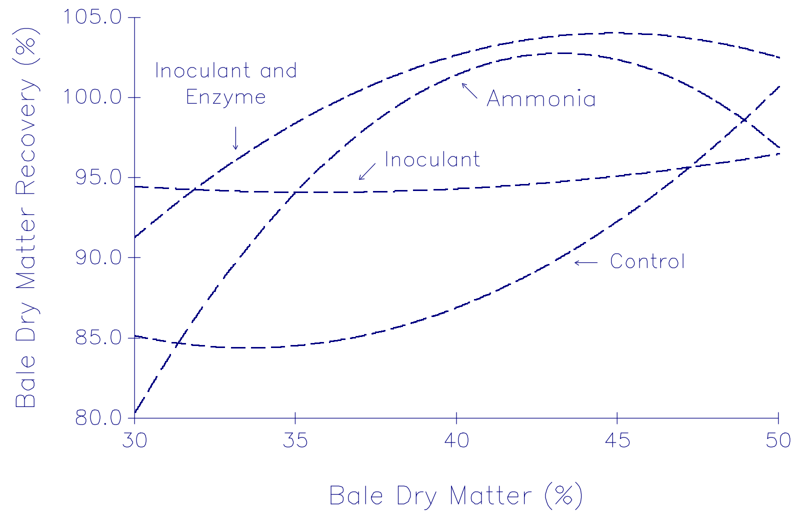


Figure 3A. Regressions of dry matter recovery (%) on dry matter (%) of bermudagrass round bale silage, 1987. Overall regression: $28.12 + 2.846X - .029X^2$; n = 110, $r^2 = .43$.

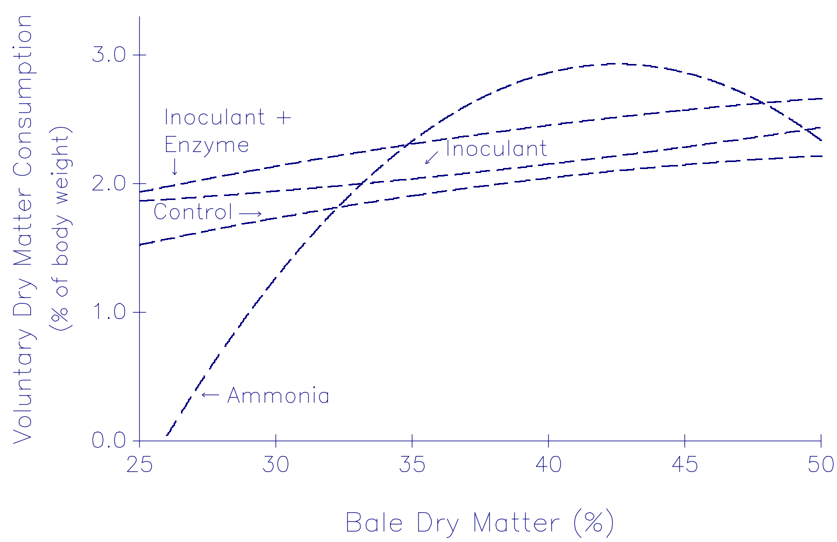


Figure 3B. Regressions of voluntary dry matter intake (expressed as % body weight) on dry matter (%) of bermudagrass round bale silage, 1987. Heifers weighing 500 lb were used in this study.

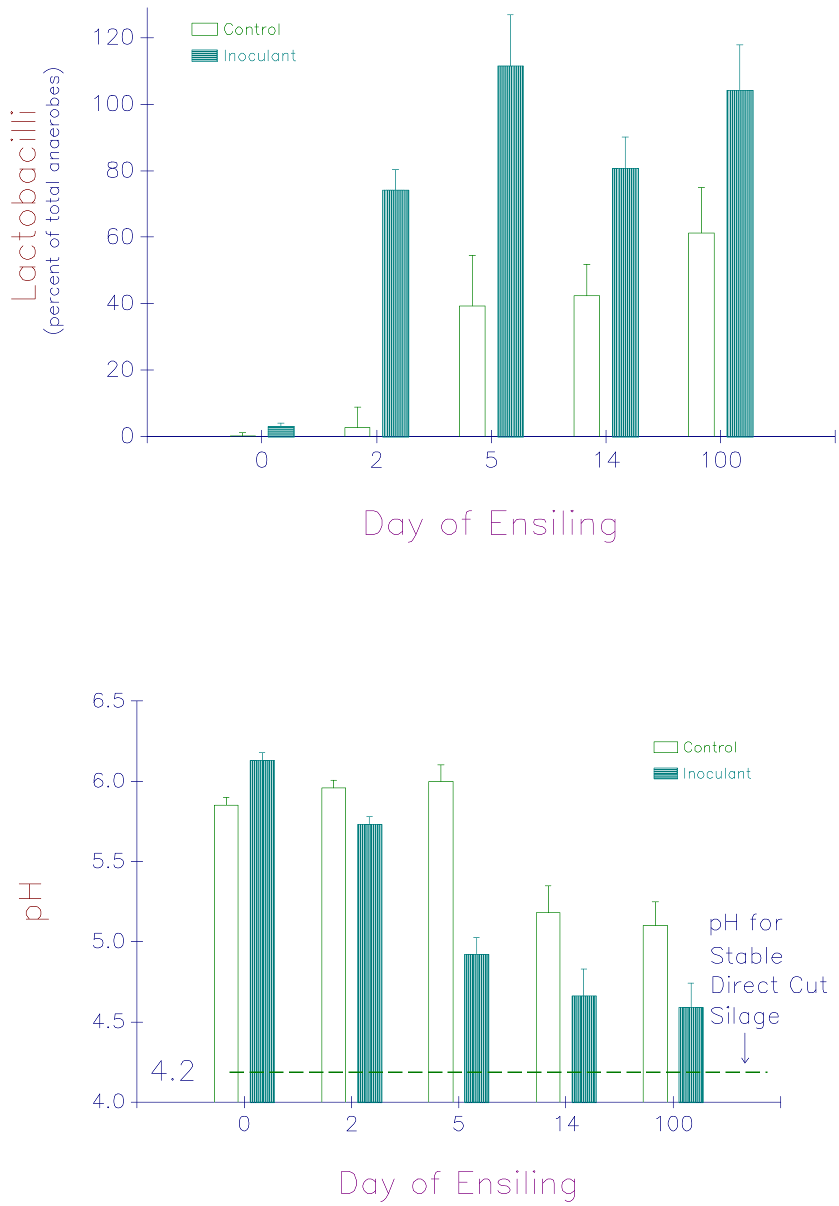
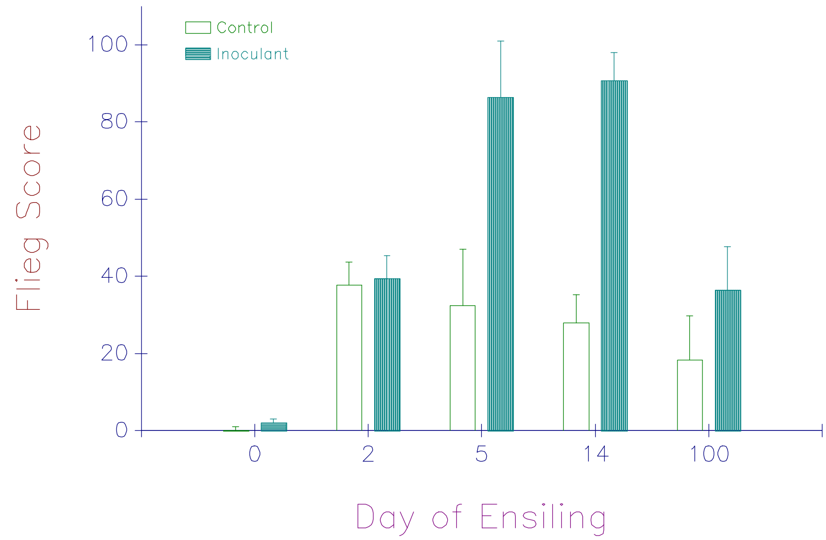


Figure 4. Effect of inoculation with lactic acid producing bacteria on: A. Number of lactobacilli (expressed as a percent of total anaerobic isolates) isolated from direct-cut bermudagrass round bale silage, and B. pH of direct-cut bermudagrass round bale silage. Note that pH of inoculated silage did not fall below pH 4.2, the pH below which silage stability is achieved.



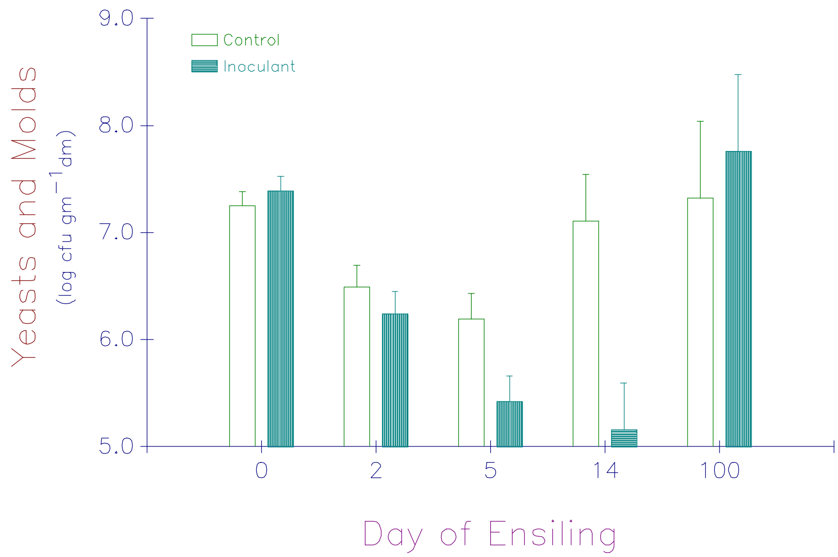
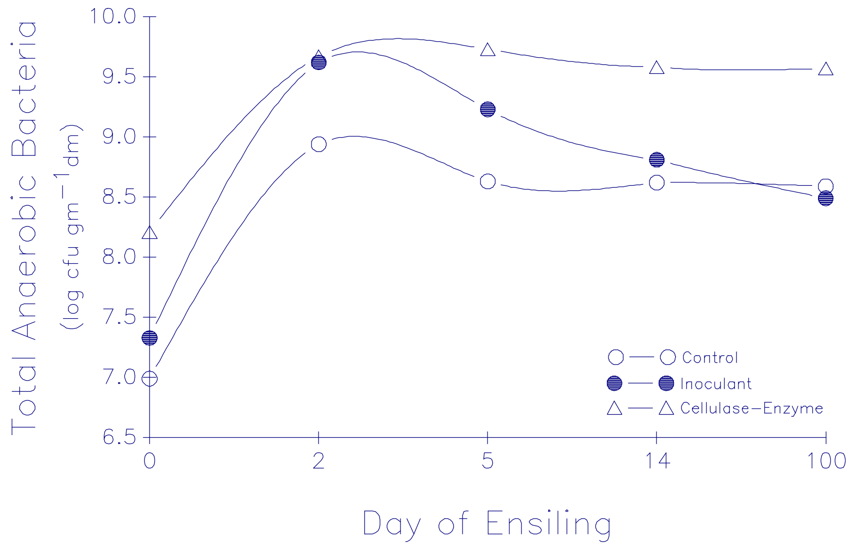


Figure 5. Inoculation of direct-cut bermudagrass round bale silage with lactic acid producing bacteria temporarily improves silage quality as characterized by: A. Increased Flieg score at day 14, and B. Decreased yeast and mold counts (CFU = Colony Forming Unit) at day 14. Unfortunately, the respective values at day 100 show that the inoculated silage was not stable.



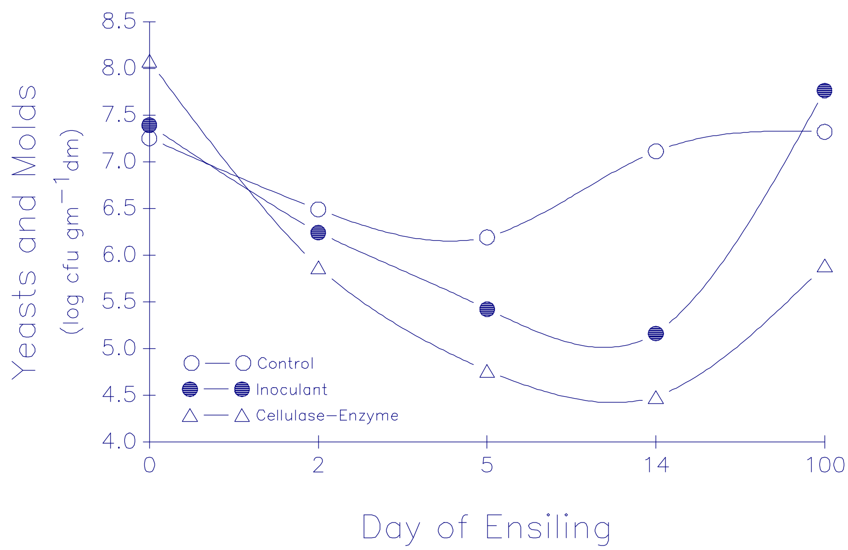


Figure 6. Effect of cellulase-enzyme on: A. Total anaerobes isolated from direct-cut bermudagrass round bale silage, and B. Yeasts and molds isolated from direct-cut bermudagrass round bale silage (CFU = Colony Forming Unit).