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# Forage Conservation in Tropical Zones: Potential and Limitations of Grass Silages in South America

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# Forage conservation in tropical zones : potential and limitations of grass silages in South America

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**Key words :** tropical grass silage, fermentation losses, additives, effluent, aerobic stability

**Introduction** In recent decades, the international literature and some national initiatives have focused on major issues concerning tropical grass silage (Sollenberger et al, 2003), and information from these studies has been helpful in compiling this review. Attempting to avoid an empirical approach to ensiling, the current review aims to prioritize this knowledge and to show that tropical forages, like other species, exhibit potentials that may be achieved and limitations that must be considered, in order to make tropical grass silage.

For decades, research on fermentation practices has examined the interrelation between dry matter (DM) levels, soluble carbohydrates and forage buffering effect. According to Wilkinson et al. (1982), when forages are ensiled with low DM levels, soluble carbohydrate levels below 2.2% on a fresh weight basis, and with low relation between the carbohydrates and the buffering capacity, the risks of secondary fermentation are higher. This calls for the meticulous use of resources to change this scenario.

Tropical grasses show low DM levels at the ideal harvest time, which can contribute favourably to the anaerobic process. However low DM levels negatively affect transportation and storage efficiency, besides reducing the fermentative capacity and delaying the pH drop.

The preservation process can be assessed based on the inevitable losses of energy and DM during ensilation. Gaseous losses due to secondary fermentation from the effluent produced in the silo, as well as aerobic deterioration, are the main sources of energy loss, which can range from 7% for well-preserved materials to 40% in poor conditions (McDonald et al., 1991).

Several categories of additives are available to help control loss and/or ensure higher aerobic silage stability. The choice of additives should be based on technical criteria.

Until recently, it was believed that the cost of tropical grass silage, in digestible energy units, was lower than that of silage made from crops such as maize and sorghum. However, recent research has shown that the main advantage of producing tropical grass silage lies in its greater potential to produce biomass yield. Biomass production alone does not meet the real objective of producers, which is high digestible DM production/ha/year. In the case of silage, the nutritional value will depend on other factors, in addition to harvesting the forage at the right time. Thus, the use of strategies aimed at improving silage quality should be meticulously planned, in order to correct limitations and to effectively achieve the species' potential.

**Effects of additives on nutritional value, physical parameters and silage losses**

**Bacterial inoculants and/or enzymes** In 2005, control of losses and the use of additives in tropical grass ensiling were identified as priority issues during the XIV International Silage Conference, which took place in Belfast (Nussio, 2005). According to Kung Jr et al. (2003), no other silage production issue received as much attention from producers and researchers in the 1980's and 90's as did bacterial inoculants. In regions where cereal grains, legumes and wilted grasses were the main crops harvested for silage, bacterial inoculants became the most used additives (Bolsen et al., 1995).

The rapid decline of pH depends on acids produced by the inoculated microorganisms interacting with the pre-existing epiphytic and endophytic populations. The efficiency of lactic acid synthesis from glucose is historically linked to homo-fermentative bacteria (McDonald et al., 1991). Because the epiphytic population is variable, often there is the need to add extra sources of microorganisms.

According to Muck (1996), if the population of epiphytic bacteria is higher than that added through inoculation, it is likely that the added bacteria will not be effective.

Therefore a lack of observable benefits from bacterial inoculation could be due to the existence of a desirable epiphytic or endophytic population of microorganisms but, in other cases, the lack of a positive response may be linked to the inappropriate microorganisms or to the absence of fermentable subtrates, which would not allow either the epiphytic or inoculated microorganisms to act on the chopped forage. This last condition provides the rationale for another category of additives, the nutrient-supplying sources, which will be discussed below.

The epiphytic population of microorganisms originally found in tropical forages, as well as its colonization process from the harvesting time until the opening of the silos, has already been credited as an important factor in the final outcome of fermentation . Preliminary results of tropical forage evaluation suggest that there may be different epiphytic populations as a result of changes of plant age , the agronomic handling procedure used and the particular species studied (Santos , 2007) .

**Table 1** *Bacterial populations of lactic acid bacteria (BAL) and enterobacteria (ENT) during fermentation of signal grass (Brachiaria decumbens Stapf .) silages at different ages of regrowth .*

| | Fermentation period (days) | | | | | | |
|---|---|---|---|---|---|---|---|
| Age (days) | 0[1] | 1 | 3 | 7 | 14 | 28 | 56 |
| | | | | BAL (log CFU/g) | | | |
| 30 | 3 .93 | 6 .60 | 6 .43 | 7 .99 | 7 .99 | 7 .81 | 5 .54 |
| 40 | 4 .81 | 6 .84 | 7 .57 | 8 .25 | 8 .25 | 8 .22 | 6 .15 |
| 50 | 5 .37 | 6 .20 | 7 .81 | 8 .69 | 8 .39 | 8 .31 | 6 .51 |
| 60 | 5 .32 | 7 .85 | 8 .03 | 8 .75 | 8 .45 | 8 .40 | 7 .21 |
| 70 | 5 .51 | 7 .82 | 8 .53 | 8 .90 | 8 .79 | 7 .71 | 6 .69 |
| | | | | Enterobacteria (log CFU/g) | | | |
| 30 | 7 .68 | 7 .84 | 7 .85 | 6 .79 | 5 .76 | 4 .54 | nd |
| 40 | 7 .55 | 6 .84 | 6 .56 | 6 .70 | 4 .70 | 4 .47 | nd |
| 50 | 7 .49 | 7 .22 | 6 .38 | 4 .63 | 4 .49 | 3 .32 | nd |
| 60 | 7 .53 | 7 .83 | 6 .343 | 4 .57 | 4 .49 | 3 .25 | nd |
| 70 | 7 .08 | 7 .89 | 6 .23 | 4 .55 | 4 .21 | 3 .20 | nd |

[1] Forage before ensiling . Adapted from Santos , E .M . (2007)

In evaluating the inoculation effects of BAL ( *Lactobacillus plantarum*) on silages of palisade grass ( *Brachiaria brizantha (A . Rich) Stapf*) produced in the summer , Ribeiro (2007) observed that the presence of the inoculant did not alter the parameters related to the fibrous fraction , except that it reduced the levels of crude protein , which resulted in silages with lower *in vitro* dry matter digestibility (IVDDM) . The inoculant also showed little effect on altering the variables evaluated , and the losses resulting from effluent production were not changed by the bacterial inoculation . Similar results were observed by Igarasi (2002) and Paziani (2004) when ensiling Guinea grass ( *Panicum maximum Jacq* .) in the presence of bacterial inoculant , and by Loures (2004) who exposed the same forage species to the action of fibrolytic enzymes associated with homo-fermentative bacteria . However , Ribeiro (2007) reported that the inoculation was responsible for increased gaseous losses , which reduced the DM recovery , as shown in Figure 1 .

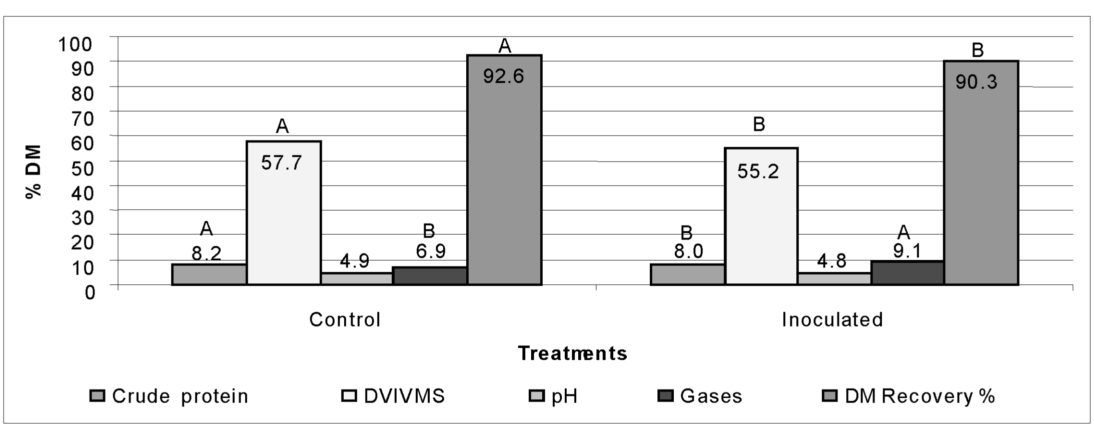


**Figure 1** *Nutritive value and physical parameters of palisade grass silages , produced in the summer , with or without the presence of bacterial inoculant . Adapted from Ribeiro (2007) .*

Ribeiro (2007) also evaluated the effects of an inoculant containing strains of BAL represented by *Lactobacillus plantarum* MA 18/5U and *Pediococcus acidilactici* MA/5M (1 .0 × $10^5$ and 3 .0 × $10^4$ CFU variables/g fresh forage , respectively) in palisade grass harvested at 54 days of vegetative regrowth . When inoculated silages were compared to the control treatment , the bacterial inoculant containing two strains of BAL , which act at distinct steps along the fermentative process , stood out because it preserved more of the protein fraction (8 .1 vs . 7 .3% DM) , because it elevated the digestibility coefficient of the organic matter IVDOM (59 .8 vs . 57 .9%) , and because it reduced the pH values (4 .0 vs . 4 .4) and gaseous losses (3 .6 vs . 6 . 3% DM) , thus leading to better recovery of DM (95 .7 vs . 93 .1%) , . Although less efficient than the strains of *Lactobacillus* *plantarum* , *Pediococcus* bacteria can reduce pH when the environment does not suit the *Lactobacillus* bacteria (Kung Jr et al , 2003) . According to Ribeiro (2007) , the quick pH drop and the higher speed of lactic acid production were probably responsible for the beneficial effects where inoculated silages with two strains of microorganisms gave highest levels of lactic acid (4 .3 vs . 2 .6% DM) .

When exposed to the aerobic environment during the handling and removal processes , silages inoculated with BAL are more unstable , due to reduced production of anti-fungal compounds (Ranjit and Kung Jr . , 2001) . This fact was corroborated by Ribeiro (2007) , when silages of palisade grass , inoculated with BAL , were shown to have higher levels of lactic acid and were less stable when submitted to evaluation in aerobic conditions .

Under such conditions , it is desirable to use additives containing hetero-lactic bacteria , which produce propionic acid in addition to lactic and acetic acids . Recently , the use of *Lactobacillus buchneri* , deficient in ethanol production , has been encouraged in order to ensure satisfactory fermentation , associated with the effective inhibition of yeasts and fungi , consequently providing more aerobic stability . However , Ribeiro (2007) found no positive effects from inoculating *L . buchneri* to increase the number of hours of stability of silages of palisade grass , or to reduce DM losses after 100 hours of exposure to the environment (4 .7 , 4 .9 and 5 .1% respectively for control silages and for silages inoculated with *L . buchneri* or *L . plantarum*) . The unstable performance of L .*buchneri* may be due to the low levels of dry matter of tropical forage , or to environmental factors which reduce the effectiveness of *L . buchneri* . Additionally , wet tropical grass silages (<25% DM) when exposed to aerobic deterioration usually do not increase in temperature easily because the prevailing microbial colonization is by bacteria rather than by yeasts and moulds . The high pH (>4 .5) , lack of substrate and high concentration of acetic and propionic acid might also explain this trend (Bernandes et al 2005) .

**Fermentation inhibitors** The fermentation inhibitors currently available replace the elevated doses of acids (formic , benzoic and citric) in their pure form , by salts from these acids . The organic salts are being developed commercially , as in the case of ammonium formate . This salt from formic acid , soluble in water , exhibits acid reducing properties and , when dissociated , makes formic acid and ammonia available to the environment .

Results from using these new additives are consistent in European countries , where the main species used for ensiling are legumes and grasses from relatively temperate climates . However , in tropical regions , experiments assessing the use of fermentation inhibitors for tropical grass silages are at preliminary stages , justifying the need for ongoing research .

Ribeiro (2007) evaluated the effects of two commercial additives , here described as AF62 (62% of formic acid , 24% of ammonium formate and 14% of water) and AF44 (44% of formic acid , 30% of ammonium formate , 9% of propionic acid , 2% of benzoic acid and 15% of water) , on the nutritional value , DM losses and physical parameters of palisade grass silages , harvested in the summer at 54 days of vegetative regrowth .

Figure 2 shows that both additives were effective in lifting the protein content of silage , probably due to the lower occurrence of proteolysis and deamination resulting from the control of undesirable microorganisms (McDonald et al . ,1991) . The additives also improved the nutritional value of the silages by increasing soluble carbohydrate content , reducing gaseous losses and increasing IVDOM (Figure 2) . In ensiling forages in south Chile , with or without formic acid and ammonium formate , Siebald et al . (2003) also observed higher IVDOM in the silages , due to a better fermentative process .

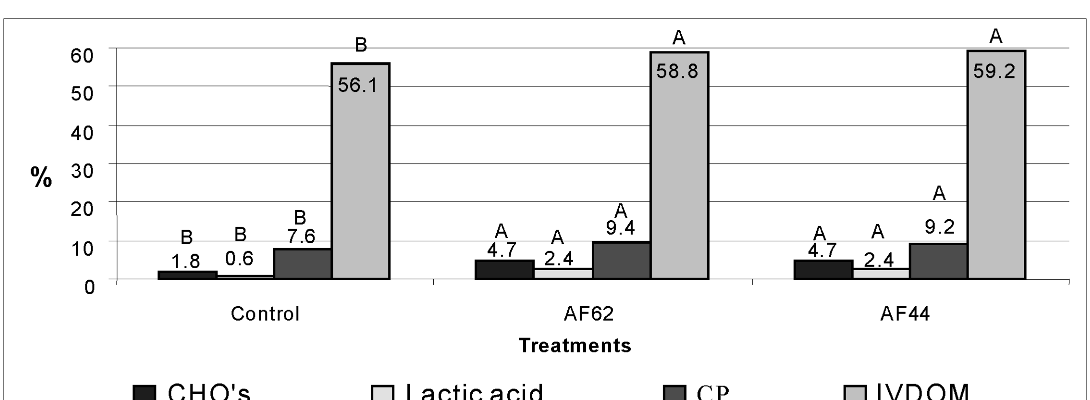


**Figure 2** *Levels of soluble carbohydrates (% DM) , lactic acid (% DM) , crude protein (CP ,% DM) and IVDOM (% MO) of palisade grass silages treated with additives . Adapted from Ribeiro (2007) .*

The effluent production, however, was increased in the presence of these additives (Figure 3). This corroborates the results of McDonald et al. (1991) in that the concentration of non-dissociated fatty acid increased significantly due to the low pH reached and this could induce the higher exposure of the cellular content. In spite of this, by reducing gaseous loss (a key component of total losses) the addition of salt from formic acid resulted in inoculated silages with better DM recovery (Ribeiro, 2007).

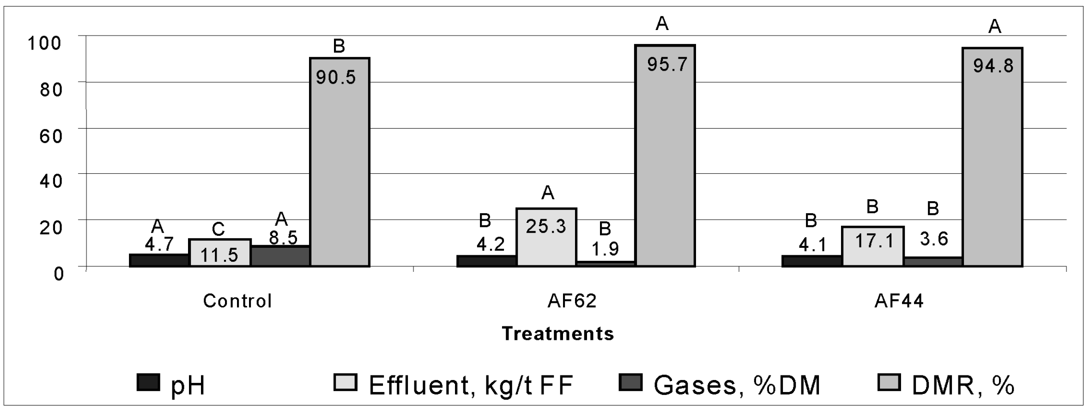


**Figure 3** *pH values, effluent yield (kg/t fresh forage), gases loss (% DM) and DM recovery (%) of palisade grass silages treated with additives. Adapted from Ribeiro (2007).*

The AF44 additive also favored a higher aerobic stability of the silage. The most likely explanation is that although AF44 contained a smaller quantity of formic acid than AF62, it contained propionic and benzoic acids, and these lifted the levels of lactic and acetic acids very significantly.

**Nutrient sources and/or moisture absorbents** According to Sollenberger et al. (2003), when it comes to tropical grasses, satisfactory ensilation depends on the quantity of soluble carbohydrates made available to the microorganisms, regardless if the silage is or is not inoculated. This suggests that the epiphytic population of bacteria would not be the exclusive limitation to producing quality silages.

Results of some experiments in which tropical grass silages were produced in the summer and inoculated with moisture absorbent sources and/or nutrient supplies are summarised in Table 2. With exception of Igarasi's (2002) trial, in which the presence of pelleted citrus pulp did not reduce effluent yield, in the other studies the addition of this agro-industrial co-product or ground millet kernel or pelleted soybean hulls considerably reduced the effluent surge, which would be explained by the high absorptive capacity of these materials.

**Table 2** *Nutritional value and physical parameters of silages from tropical grasses, with or without absorbent sources and/or nutrients.*

| | Variables[2] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silage[1] | DM | CHO's | N-$NH_3$ | NDF | IVDDM | pH | Gases | Effluent | DMR | Author (s) | Source | % Additive |
| W/O | 20.7$^B$ | 1.51 | 23.5$^A$ | 66.9$^A$ | 48.6$^B$ | 4.7 | 13.9$^A$ | 16.0$^A$ | 84.7$^B$ | Ribeiro | Palisade grass | 7.5 |
| PCP | 24.5$^A$ | 2.03 | 14.4$^B$ | 57.9$^B$ | 52.9$^A$ | 4.9 | 4.7$^B$ | 0.80$^B$ | 95.3$^A$ | (2007) | | |
| | DM | CHO's | N-$NH_3$ | NDF | IVDDM | pH | Gases | Effluent | DMR | Author | Source | % Additive |
| W/O | 20.3$^B$ | 0.50 | 10.6$^A$ | 70.2$^A$ | — | 4.9 | 6.7 | 52.9$^A$ | 93.6 | Paziani | Palisade grass | 13.7 |
| GM | 29.6$^A$ | 0.70 | 2.4$^B$ | 45.8$^B$ | — | 4.9 | 5.7 | 19.0$^B$ | 94.0 | (2004) | | |
| | DM | CHO's | N-$NH_3$ | NDF | IVDDM | pH | Gases | Effluent | DMR | Authors | Source | % Additive |
| W/O | 24.1$^B$ | — | 34.7$^A$ | 73.9$^A$ | — | 4.9$^A$ | — | — | — | Bergamaschine | Palisade grass | 10.0 |
| PCP | 31.1$^A$ | — | 6.7$^B$ | 62.1$^B$ | — | 4.1$^B$ | — | — | — | et al. (2006) | | |
| | DM | CNF | N-$NH_3$ | NDF | TDN | pH | Gases | Effluent | DMR | Author | Source | % Additive |
| W/O | 13.7$^B$ | 10.1$^B$ | — | 68.2$^A$ | 47.7$^B$ | 5.4$^A$ | 9.0$^A$ | 44.0 | 83.4$^B$ | Igarasi (2002) | Guinea grass | 13.0 |

(continue)

| | Variables[2] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silage[1] | DM | CHO's | N-$NH_3$ | NDF | IVDDM | pH | Gases | Effluent | DMR | Author (s) | Source | % Additive |
| PCP | 26.5$^{A}$ | 26.9$^{A}$ | — | 56.4$^{B}$ | 57.8$^{A}$ | 3.9$^{B}$ | 2.6$^{B}$ | 42.9 | 91.0$^{A}$ | | | |
| | DM | CHO's | N-$NH_3$ | NDF | IVDDM | pH | Gases | Effluent | DMR | Author | Source | % Additive |
| W/O | 24.2$^{B}$ | 2.25$^{B}$ | 10.9$^{A}$ | 61.1 | 56.1$^{B}$ | 4.7$^{A}$ | 8.5$^{A}$ | 11.5$^{A}$ | 90.5$^{B}$ | Ribeiro(2007) | Palisade grass | 10.0% |
| PCP | 29.4$^{A}$ | 5.22$^{A}$ | 7.1$^{B}$ | 63.9 | 59.1$^{A}$ | 3.8$^{B}$ | 2.4$^{B}$ | 5.0$^{B}$ | 97.1$^{A}$ | | | |
| SBH | 28.9$^{A}$ | 2.72$^{B}$ | 11.9$^{A}$ | 61.7 | 58.4$^{A}$ | 4.6$^{A}$ | 7.9$^{A}$ | 4.9$^{B}$ | 91.6$^{B}$ | | | |

[1] W/O-non-inoculated silage; PCP-pelleted citrus pulp; SBH-pelleted soybean hulls; GM-ground millet kernel.
[2] DM-dry matter (%); CHO's-soluble carbohydrates (% DM); N-$NH_3$-ammonia nitrogen (% Total N); NDF-neutral detergent fiber (% DM); IVDDM (OM)-in vitro digestible dry matter or organic matter; Gases (% DM); Effluent (kg/ t fresh forage); DMR-dry matter recovery (%); CNF-non-fibrous carbohydrates (% DM); TDN-total digestible nutrients (% DM).
Source: Adapted from Ribeiro (2007), Bergamaschine et al. (2006), Paziani (2004) and Igarasi (2002).

Adding citrus pulp increased the recovery of DM, probably because of lower gaseous losses observed in inoculated silages. Igarasi (2002) and Bergamaschine et al. (2006) showed that the presence of citrus pulp improved the fermentative characteristics of silages (lower pH values and levels of ammonia-N).

The authors showed that citrus pulp and soybean hulls increased the nutritional value of the silages, ie the total digestible nutrients (NDT) or the digestibility of the DM (IVDDM). The benefits may have resulted from a number of factors, among which may have been the higher fermentative capacity of the ensiled material, in the presence of added sources of fermentable subtrates, mainly soluble carbohydrates.

The lower pH values of these silages, due to higher synthesis of lactic acid by BAL, are indicators that the speed of pH decline may have been high, which would have resulted in rapid fermentation and, therefore, higher preservation of nutrients. The chemical composition of the pearl millet kernel and citrus pulp probably explains the lower levels of NDF of the inoculated silages and helps explain their higher nutritional value. The additional supply of soluble carbohydrates, through nutrient sources, is a preponderant factor, when compared to the inoculation of microorganisms, to obtain silages of tropical grasses of higher nutritional value and DM recovery. It is important to point out that these sources not only increment the availability of subtrates, but also increase DM levels of the ensiled mass.

**Silage potential of tropical grasses** In general terms, with the exception of bacterial inoculation which, in most trials, has not been effective in improving nutritional value or reducing losses, the treatments evaluated in this review have been effective experimentally in providing a better fermentation profile, producing silages with a higher nutritional value and more DM recovery. However, the nutritional value benefits were not always confirmed in farm-scale silos and, in practice, benefits in animal performance have not often been assessed and in some cases have been negligible. In some cases, the explanation of the ineffectiveness of additives is based on the timing of their application.

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