

Additives to Improve the Silage Making Process of Tropical Forages

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1. Introduction

This contribution focuses on the ensilage of forages produced in tropical and sub-tropical climates.

The low dry matter (DM) and water soluble carbohydrate (WSC) content of tropical (C₄) grasses results in poor fermentation of freshly cut material and depending on climatic conditions wilting must be extended without having a positive effect on fermentation patterns, whilst increasing ammonia-N (Table 1). Use of certain additives may be an alternative to wilting, particularly with thick-stemmed , erect fodder crop grasses (*Pennisetum*, *Panicum*, etc.) that produce a large mass of plant material where pre-conditioning and handling is difficult to mechanise and labour-consuming. Tropical forage grasses (*Cynodon* , *Brachiaria*, *Digitaria*, *Setaria*, *Chloris* etc.) can be wilted more easily but, when done so excessively, affecting compression in the silo and thus fermentation quality (Catchpoole and Henzell 1971). Even under controlled wilting conditions additives are being recommended to improve fermentation and nutritive value of conventional as well as round bale silages (Bates *et al.* 1989, Staples 1995).

In farm situations silage making often faces drawbacks which compromise the basic principles of silage making, especially where technology is limiting such as with smallholders in the tropics and subtropics (Bayer and Waters-Bayer, 1998). Additive can never be a substitute for good ensiling management. For example, additives will not make up for the negative effects on fermentation quality of a tropical forages caused by practices such as the use of low quality oxygen-permeable plastic covers and extended storage under temperatures in excess of 30°C (Tjandraatmadja *et al.* 1991).

It should also be emphasised that the efficacy of any additive will ultimately be assessed by animal performance and by DM recovery from the silo which are parameters not commonly determined . Most of the experiments are restricted to measurements of traditional fermentation patterns under controlled laboratory conditions where even untreated silages made from thick-stemmed *Pennisetum* species may show acceptable preservation (Woodard *et al.* 1991, Spitaleri *et al.* 1995). On the other hand, bad fermentation products such as biogenic amines which cause intake depression in ruminants (Phuntsok *et al.* 1998) are not detected by conventional silage analysis. It has been suggested that the current parameters used to predict silage fermentation and quality may need some re-evaluation (Jones 1995).

2. Biological additives

Inoculants and enzyme preparations are regarded as natural products which are safe to handle, non-corrosive to machinery, do not cause environmental problems and their usage has expanded remarkably in the last decades. Perhaps no other area of silage management has received as much attention among both researchers and livestock producers as bacterial inoculants

(Bolsen 1999). There are many commercial products with variable efficacy available. However, dosage and method of application are decisive for effectiveness.

Inoculants

Based on a survey of inoculant studies, Muck (1993) concluded that inoculants are most successful in alfalfa and temperate grass silages and that with corn silage their success has been limited. However, Bolsen (1999) emphatically recommended that bacterial inoculants should be applied to every load of forage ensiled, based on results from over 200 laboratory-scale studies and from 28 farm-scale trials where this type of additive consistently improved fermentation efficiency, dry matter recovery, food efficiency, and liveweight gain per ton of crop ensiled in corn and forage sorghum silages.

Table 1. Effects of wilting on fermentation of tropical fodders (Part 1).

	Forage		
	Dry matter (%)	Water soluble carbohydrates (% of fresh material)	True protein (% of crude protein)
Elephant grass*			
120 days growth , unwilted	19,7	2,17	88,0 ^a
Wilted for 50 h	26,6	3,00	62,0 ^b
Millet*			
45 days regrowth , unwilted	16,0	2,70	82,1 ^a
Wilted for 48 h	31,0	4,24	58,5 ^b
78% Millet+ 22% Cowpea, unwilted ⁺	20,8	1,40	78,6 ^a
Wilted for 26 h	46,2	3,19	71,6 ^b
60% Eleph.grass+40% Cassava tops ⁺⁺			
Unwilted	20,5	1,62	84,7 ^a
Wilted for 20 h	26,5	2,81	76,1 ^b

Table 1. Effects of wilting on fermentation of tropical fodders (Part 2).

	Silage				
	Ammonia N (% of total N)	pH	Total acids (% of dry matter)	Butyric acid (% of total acids)	Lactic acid (% of total acids)
Elephant grass*					
120 days growth, unwilted	9,4 ^b	4,4	5,9	2,4	66,6
Wilted for 50 h	14,8 ^a	4,5	5,1	4,1	41,7
Millet*					
45 days regrowth, unwilted	6,2 ^b	4,0	7,4 ^a	0,9	78,6
Wilted for 48 h	10,3 ^a	4,2	4,5 ^b	2,0	60,6
78% Millet+ 22% Cowpea, unwilted ⁺	8,9	3,64 ^b	7,5 ^a	0,3	72,7
Wilted for 26 h	7,5	3,85 ^a	6,5 ^b	0,3	71,3
60% Eleph.grass+40% Cassava tops, ⁺⁺	9,5 ^b	3,8	8,9 ^a	2,1	83,4
Wilted for 20 h	11,7 ^a	3,9	7,3 ^b	2,2	79,5

^{ab}Means within column differ, $P < 0,05$

* Pinheiro Machado and Mühlbach, 1986.

⁺Figueiredo and Mühlbach, 1984.

⁺⁺Zanotelli and Mühlbach, 1989.

Enzymes

The addition of enzyme preparations either alone or combined with inoculants is proposed as a strategy to increase available substrate to improve lactic acid fermentation in silage and/or to increase nutritive value of forage. With silages of temperate forages produced in subtropical conditions an inoculant/enzyme mixture (Sill-All®) improved fermentation quality of unwilted forage oats (*Avena strigosa*) (Berto and Mühlbach 1997) and reduced NDF contents of both unwilted and wilted alfafa (Rangrab *et al.* 1996). The complex interactions occurring with the addition of both products is not completely understood and earlier results indicate varying degrees of success

(Jaster 1994) . The first products were based on complexes containing ill-defined amounts of various enzymes from crude fermentations of fungi and results were inconsistent due to variable application rates, plant species, plant maturity , and DM content of the materials (Muck 1993).

Similarly, results have also been conflicting in experiments where enzymes were added to corn silage with no clear effects on fermentation characteristics, despite a decrease of ADF, NDF, and hemicellulose contents (Sheperd and Kung 1996). Positive results with cellulase in combination with organic acid have been reported with the ensilage of temperate grass forages (Nadeau *et al.* 1996).

More recently, newer enzyme preparations have prompted a renewed interest in the potential of these products also as feed additives for ruminants , enhancing forage digestion and milk production (Yang *et al.* 1999, Schingoethe *et al.* 1999).

Results with tropical forages

If different types of additive suit different crops (Wilkinson 1998) one should not expect that the effects achieved with biological additives on the ensilage of temperate forages will also be realised with tropical species, where fibre contents are generally much higher and more lignified. It stands to reason to consider that the constraints imposed by structural, anatomical and chemical characteristics which are peculiar to tropical forages and which impair nutritive value, i.e. intake and fermentation in the rumen (Wilson 1994; 1997), may also affect harvesting, wilting, chopping, and compressing the original material in the silo as well as influence the direction of fermentation.

Whilst literature on the use of biological additives for temperate forages is relatively abundant the information with tropical species is scarce. The data reviewed with this kind of additive is presented according to the type of tropical forage tested.

a) Sorghum spp.

Forage sorghum (*Sorghum bicolor* L.) is a fodder crop with a sweet juicy pith having types with finer, more numerous and more leafy stems (Bogdan 1977). Of the tropical forages it is one of the best suited for ensiling.

When harvested at the soft dough stage (29 % DM) it can have about 14 % WSC and 50 % NDF in DM and after a 30 days fermentation period the silage can still present 10 % WSC in DM. To such forage a mixture of *Lactobacillus plantarum* and *Streptococcus faecium* (Pioneer brand® 1129) was added at 1.1×10^5 CFU per gram of fresh forage in a microsilo trial. Inoculation reduced silage pH but did not affect concentration or *in vitro* digestibility of NDF or ADF, neither did it prevent aerobic deterioration (Sanderson 1993).

Froetschel *et al.* (1995) ensiled either untreated or inoculated forage sorghum harvested at the milk stage (61.5 % NDF) in 900-kg concrete tower silos. Silage lactic, acetic and total volatile fatty acids were increased 9.2 to 15.3 % and DM recovery was increased 7.1 % with inoculation. The level of response was considered cost effective in a 1.7 to 1 return for investment based on average prices for silage and inoculant. In a feeding trial with steers inoculation did not influence digestibility of DM or fibre components of silages and silage-based rations.

A sorghum-sudangrass hybrid was harvested at 90 days of growth (26 % DM) in Puerto Rico and ensiled in laboratory silos either untreated or inoculated with 10^6 CFU of *Lactobacillus plantarum* mixed or not with a multi-enzyme complex containing arabinase, cellulase, β -glucanase, hemicellulase and xylanase, applied at 0.1 % of fresh material. The addition of inoculant either alone or in mixture with the enzyme complex improved silage quality as evidenced by lower pH and a greater population of lactic acid bacteria (Rodriguez *et al.* 1994 a). However, additives did not reduce aerobic deterioration of forage sorghum ensiled in a tropical environment (Rodriguez *et al.* 1994 b).

Similar results with the ensilage of *Sorghum bicolor* were obtained more recently by Cai *et al.* (1999), where selected strains of either *Lactobacillus casei* FG 1 or *Lactobacillus plantarum* FG 10 isolated from corn and *Panicum maximum* were used at 10^5 CFU per gram of fresh matter. Both inoculants effectively improved fermentation decreasing contents of volatile fatty acids and ammonia N and reducing gas production and DM loss as compared to the control silage. Again, the LAB-treated sorghum silages which contained relatively high concentrations of residual WSC and lactic acid suffered a faster aerobic deterioration than the control silage.

Johnson grass (*Sorghum halepense*) is a rhizomatous perennial, aggressive forage which can be established from seed for pasture and fodder (Mannetje and Jones 1992). This forage was harvested at 45 (22,6 % DM) and 110 days of regrowth (43,8 % DM), chopped into 2.5 cm pieces, and ensiled in laboratory silos either untreated or treated with a mixture of *Lactobacillus plantarum* at a rate of 10^6 CFU per gram of fresh material plus 0.1 % of a multi-enzyme complex with arabinase, cellulase, β -glucanase, hemicellulase and xylanase (Rodriguez *et al.* 1998).

For both stages of regrowth, Johnson grass treated with microbial inoculant plus enzymes had lower pH and higher populations of lactic acid bacteria and higher lactic acid contents than untreated silages. Silage additives also decreased butyric acid content in grass ensiled at 45 days regrowth and ethanol content in the more mature forage. However, the authors also conclude that the resulting silage did not meet the criteria to be considered as good quality silage, suggesting for more research to evaluate other sources of additives as well as the rates of additives used.

b) *Pennisetum* spp.

Elephant or Napier grass (*Pennisetum purpureum*) has thick erect stems 2-6 m tall, with 30-120 cm long leaves and has been introduced to practically all tropical countries being widely grown for fodder and less often for grazing (Mannetje and Jones 1992). Van Onselen and López (1988) reported on a trial from 1981 with the use of a commercial enzymatic product (sucrase and cellulase) added to elephant grass from a 105 days regrowth (19,4 % DM) at a rate of 0.1 % of fresh forage plus 0.9 % corn meal. When compared to a control treatment with 7 % corn meal the enzymatic product showed higher pH and ammonia-N values and a lower lactic acid content resulting in a silage of bad quality.

A 60 days regrowth of elephant grass (14 % DM, 70 % FDN in DM) was ensiled in 200-liter plastic containers testing the effects of two commercial products with bacteria and enzymes (Bio-Silo ® and Bio-Silo P.U. soluble®, Katec Kaiowa Ltda., Brazil). The product Bio-Silo was added at 0.1 % of forage fresh matter plus 0.9 % of corn meal and Bio-Silo P.U. was diluted in water and also added at 0.1 %, according to the manufacturer's recommendations. No effects of additive use were detected neither

on silage composition and pH and ammonia-N values nor on nutrient intake and digestibility coefficients measured with sheep (Henrique and Bose 1992).

Tamada *et al.* (1999) conducted experiments in different latitudes in Japan with different harvest dates of Napier grass and two silage storage temperatures to test the effects of a mixture of cellulases (*Acremonium cellulolyticus* and *Trichoderma viride*) mixed or not with a commercial inoculum (*Lactobacillus casei*, 10^8 CFU/ kg wilted forage) and of a preparation of fermented green juice extracted from macerated Napier grass mixed or not with the cellulases, as compared to a control. All treatments were applied to wilted Napier grass (averaging 22.7 % DM and 4.6 % WSC in DM) ensiled in 0.9-liter bottles; in two experiments, 40 g of glucose/kg wilted forage was included to each treatment with additive. Improved fermentations with lower pH values and ammonia contents and increased lactic acid over control only were obtained when sufficient fermentable substrate was secured by adding the cellulases or glucose.

Kikuyu grass (*Pennisetum clandestinum*) is a creeping perennial with strong, thick stolons which requires fertile soil, can be associated with white clover and is not well adapted to high temperatures (Mannetje and Jones 1992). De Figueiredo and Marais (1993) used wilted kikuyu grass (30 % DM, 3.2 % WSC in DM) treated with inoculant alone (*Lactobacillus acidophilus* + *Lactobacillus bulgaricus* at 5×10^4 / g grass ensiled) or in combination with two different enzyme preparations (either from *Trichoderma reesei* or from *Aspergillus*). The best fermentation with lower pH and ammonia-N and higher lactic acid in micro-silos of polythene bags was obtained with the combination of inoculant plus the enzyme from *T. reesei* . In a second experiment the authors used the same forage unwilted (19.2 % DM, 3.7%

WSC) without or with an inoculant (*Lactobacillus plantarum* strain MTD/1) alone and in combination with molasses meal (5 or 10 % on a DM basis) at ensiling. The only significant effect as compared to untreated silage was a pH decrease with the inoculant combined to the 10% molasses level.

Pearl millet (*Pennisetum americanum*) – A late summer crop of pearl millet grain hybrid (HGM-100) at the soft dough stage of grain maturity (18.9 % DM, 60.2 % NDF in DM) was wilted, treated with inoculant (Pioneer 1174®) and stored in a concrete stave silo. The resulting silage was poorly preserved, with a predominantly acetic fermentation (4.23 % acetic acid in DM) and the need to add a low level of readily available carbohydrates was indicated (Utley *et al.* 1995).

c) Other genera

Bermudagrass (*Cynodon dactylon*) is a stoloniferous and rhizomatous perennial, growing in the tropical, subtropical and warm temperate regions, with cultivars that tolerate frosts (Mannetje and Jones 1992). Wilted bermudagrass conserved as round bale silage is being used in the southeastern United States as an alternative to hay making and some of the first tests with a combination of enzymes containing cellulase and an inoculant showed potential to improve fermentation and dry matter recovery (Bates *et al.* 1989).

A thorough study by Umaña *et al.* (1991) was conducted with Tifton 81 bermudagrass which was harvested at the late jointing stage of growth and ensiled either wilted (32.4 % DM, 2.85 % WSC in DM) or wilted (44.1 % DM, 4.14 % WSC in DM). Both materials were chopped and either left untreated or a) with dried

sugar cane molasses at 5 % of forage DM added, b) inoculated with a mixture of *Lactobacillus plantarum* and *Streptococcus faecium* (1174 Pioneer ® at 3×10^5 CFU/g DM), c) prepared with a combination of the inoculant treatment plus the dried sugar cane molasses, all treatments being packed by hand in 19-liter plastic containers. According to the authors, all unwilted silages went through a less than satisfactory fermentation, whilst the application of molasses and inoculant to wilted bermudagrass had an additive effect and produced stable silages having the lowest pH, lowest concentration of ammonia, and greatest lactic acid concentration and *in vitro* organic matter digestibility. Hence, according to the Cooperative Extension Service from the University of Florida adding a bacterial inoculant and molasses to wilted bermudagrass is more beneficial than adding just molasses or inoculant alone (Staples 1995).

Rhodesgrass (*Chloris gayana*) is a stoloniferous creeping or occasionally tufted perennial that thrives under a wide range of tropical and subtropical temperatures (Mannetje and Jones 1992). Ridla and Ushida (1998) used a first growth of rhodesgrass harvested at the heading stage (21.8 % DM, 5% WSC and 66.4 % NDF in DM) ensiled in 2-liter vinyl bottle silos. An inoculant with *Lactobacillus casei* was added at 10^5 CFU/ g fresh sample either alone or combined with increasing levels of cellulases (A - *Acremonium cellulolyticus* and/or M - *Trichoderma viride*). The combined treatment of inoculant plus enzymes showed lower pH values and higher lactic acid contents with increasing amount of cellulase addition. All combined treatments reduced NDF, ADF and *in vitro* DM digestibility of silages compared with the untreated silage, probably meaning that enzymes hydrolyzed especially the more digestible components of plant cell wall. The combinations inoculant plus cellulase A were the most effective. A parallel test with fermentation temperatures suggested that

samples incubated at 40°C resulted in better silages than those at 20 or 30° C. It is also concluded that the absence of effect in the inoculant treatment was due to the low WSC available in rhodesgrass. These same treatments were also applied to italian ryegrass harvested at the heading stage (21.7% DM, 7.2% WSC and 59.2% NDF in DM) and the results on NDF and ADF disappearances of the inoculant and enzyme mixtures as compared to those with rhodesgrass suggest that the cell wall components in rhodesgrass silages were more resistant to degradation by the cellulases (Ridla and Ushida 1999 b). In general , within the various treatments regarding fermentation products and chemical composition, ryegrass produced better silages than rhodesgrass (Ridla and Ushida 1999 a).

Weeping lovegrass (*Eragrostis curvula*) is a densely tufted perennial, stems slender to robust, 30-120 cm high, drought-resistant (Bogdan 1977). A six weeks growth of this forage (37.8 % DM, < 2 % WSC, 79.2 % NDF) was ensiled unwilted, but treated with an inoculant/enzyme mixture (Sill-All® with *L. plantarum*, *S. faecium* and *Pediococcus acidilactici* at 10⁶ CFU/ g fresh material) resulting in a silage with lower pH, ammonia-N, butyric and acetic acid content and a higher lactic acid content compared to the control silage (Meeske 1998).

3. Feed ingredients and by-products as additives

The incorporation of easily fermentable feed ingredients such as sugar or molasses to low DM sugar-limited tropical forages is a way to improve silage fermentation. Feed-grade products such as grains in general and processed by-products such as corn or sorghum meal, rice bran, cassava meal , citrus pulp, etc. can also

be used as additives partly to provide fermentable substrate but also to direct the course of fermentation by absorbing excessive moisture. To optimize their effectiveness by avoiding effluent losses they have to be used in relatively high rates (aiming a DM content > 25 % of the mixture) and adequately mixed with the chopped forage, which demands extra labour and/or appropriate equipment. This type of additive may be of seasonal and local supply and cost effectiveness should also consider the improvement achieved in nutritive value.

Molasses

Cane molasses (75 % DM) has been widely used added up to 10 % w/w to provide fast fermentable carbohydrate for the ensilage of tropical herbage. Due to its viscosity it is difficult to apply and should be diluted preferably with a reduced volume of warm water to minimize seepage losses. When applied to tropical grasses molasses should be used in relatively high concentrations (4 to 5%) and with crops of very low DM content, a considerable proportion of the additive may be lost in the effluent during the first days of ensilage (Henderson, 1993).

However, according to Woolford (1984) the provision of extraneous sugar alone is not sufficient to permit the lactic acid bacteria to compete with other components of the silage microflora and thus ensure preservation. So, under high moisture conditions molasses can also induce a clostridial spoilage especially with forages contaminated with soil.

Sugarcane molasses added at the rate of 3 % (w/w, fresh basis) to Napier grass (12.9 % DM, 6.6% WSC) produced silages of reasonably good fermentation quality, reducing, however, the

nutrient recovery from the silo, as compared to formic acid treated silage (Boin 1975) . The same molasses dosis also resulted in increased *in vitro* DM digestibility coefficients of Napier grass ensiled at 51, 96 and 121 days of vegetative growth (Silveira *et al.* 1973).

Dwarf elephant grass (cv.Mott) cut at 72 days regrowth (14.4 % DM, 7.1% WSC) with a high buffering capacity was treated with 4 % molasses and ensiled in 4 kg polythene bags with the resulting silage having lower pH and ammonia-N than the control silage (Tosi *et al.* 1995).

Four levels (0, 4, 8, and 12%) of dried molasses (97 % DM) were applied to chopped bermudagrass (32.4 % DM, 70.2 % NDF) pre-treated with 1174 Pioneer ® silage inoculant (1.7 l/t of forage) and packed in 19-liter plastic containers. The increasing molasses levels lowered pH, ADF, and NDF percentages and increased *in vitro* DM digestibilities in bermudagrass silages (Nayigihugu *et al.*, 1995).

Guinea grass with 4 weeks (18.6 % DM) and 8 weeks (26.5 % DM) of growth was ensiled untreated or with 4 % molasses in 400 g laboratory silos. The pH varied from 4.4 to 5.4 and from 4.0 to 4.7 and ammonia-N ranged from 23.5 to 35.3 and from 15 to 39, respectively, for untreated and molasses treated silages (Esperance *et al.* 1985).

Tjandraatmadja *et al.* (1994) tested the effects of 4% and 8% molasses added at the ensilage of *Panicum maximum* cv.Hamil, pangola grass (*Digitaria decumbens*) and setaria (*Setaria sphacelata* cv. Kazungula) harvested at 4, 8 and 12 weeks of growth. The results from a laboratory trial with 500 g-vacuum sealed silo bags kept in a dark, temperature controlled room led to the conclusion that 4 % (w/w) molasses should be sufficient to

achieve effective preservation. Pangola grass which had a highly significant different chemical composition prior to ensiling , with lower NDF and lignin content presented a dominant homo-fermentative lactic acid bacteria population in silage which was fairly well preserved even without molasses.

Starch sources

It is controversial to what extent starch is an available substrate for lactic acid bacteria (Woolford, 1984) . Jones (1988) recovered 100 and 90 % of starch from barley and oats, respectively, added at the ensilage of ryegrass, attributing an improved fermentation to the substrate available from 3 – 4 % of soluble carbohydrates or from fractions such as β -glucan contained in the cereals and not to a hydrolysis of starch.

The effects of adding molasses (5 % w/w) or ground maize (5% and 10 % w/w) to star grass (*Cynodon nlemfluensis*) mixed or not with four levels (0, 15, 30, 45 % w/w) of legume (*Desmodium uncinatum*) were studied in a laboratory trial by Sibanda *et al.* (1997). In general, both additives improved fermentation up to the level of 30 % of legume inclusion, however, molasses addition resulted in lower levels of volatile N and higher lactic acid content compared to the control and both ground maize treatments .

A first growth of Napier grass was hand-harvested under rainy conditions (8.6 % DM, 67.6 % NDF), chopped to 3 cm, treated with 4 % molasses and/or 15 % defatted rice bran (2.0 % crude fat) on the fresh grass basis and ensiled in plastic bags. DM contents of silages were 13.4 %, 20.1 % and 22.5 % and spoilage losses were 5,6%, 0.3 % and 3.0 % for treatments with molasses, rice bran and their mixture, respectively. Treatment with plain rice

bran had the highest content of acetic (6.7 % of DM) and propionic (1.4 % of DM) acids and ammonia-N but the lowest content of lactic acid. The authors (Yokota *et al.* 1998) concluded that the combination molasses/rice bran can improve the fermentation quality and enhance the utilization of the silage by goats, more than each additive as a single treatment.

Cassava (*Manihot esculenta*) tuber meal (72.1 % WSC) and coconut (*Cocos nucifera*) oil meal (17.6 % WSC) were both added (5 % wet basis) to Guinea – A (*Panicum maximum*) with 17.7 % DM and 6.3 % WSC and to NB-21 (*Pennisetum purpureum* x *Pennisetum americanum*) with 16.3 % DM and 9.9 % WSC forages, chopped (1.5 cm) and ensiled in 2 kg laboratory silos. Both additives improved fermentation as compared to untreated silages of both forages, with greater effects in silages with cassava tuber meal (Panditharatne *et al.* 1986).

Elephant grass was harvested at 75 days growth (19.4 % DM, 72 % NDF) and ensiled in 300 kg asbestos/cement containers either unwilted or wilted (29.6 % DM) both materials with or without 8 % ground sorghum grain (w/w). Wilting was achieved by exposing crushed forage stems three hours in windrow after harvesting with a mower/conditioner (New Holland). Sorghum addition to both wilted and unwilted silage increased DM contents, reduced ethanol and acetic acid contents and increased intake of digestible energy as measured in sheep (Alberto *et al.* 1993).

Silages of elephant grass cv. Guaçu were obtained adding 0, 8, 16 and 24 % (w/w) either of ground ear corn with husks, wheat bran or “sacharin” (urea treated sugar cane, with 12.6 % crude protein, 17.5 % crude fibre in DM) to unwilted forage (12.40 % DM, 10.4 % WSC) harvested with a precision chopper (3 mm chopp length) and packed into 200 l plastic containers with a layer of ground hay at the bottom to absorb effluent (Andrade and

Lavezzo 1998a). Ground ear corn was more effective to increase DM content and to restrict lactic acid production while reducing ammonia-N which reached 31.3 % and 36.2% for “sacharin” and wheat bran treatments, respectively (Andrade and Lavezzo 1998b).

The fermentation pattern of wilted elephant grass cv. Taiwan-A146 silage (8 hour wilting, 26.6 % DM, 6.74 % WSC) did not differ from silages made of unwilted grass (23.5 % DM, 7.2% WSC) prepared with a cassava starch by-product added at 2, 4, 8 or 12 % (w/w). According to the authors (Ferrari Jr. *et al.* 1999) the relatively low lactic acid levels demonstrate that the substrate was not available to lactic acid bacteria.

Citrus pulp

Fresh citrus peels have been added at the ensilage of Napier grass with levels up to 50% improving fermentation quality as measured by low pH values and low butyric acid content and adequate lactic acid production (Faria *et al.*1972). Citrus peels may contain 50 % WSC in DM but the low DM content (14 – 21%) and intensive initial fermentation lead to high seepage losses causing a serious pollution problem (Ashbell 1992).

Dried citrus pulp added at the ensilage to low DM forages may increase its weight by 145 % by absorbing excessive moisture thus preserving nutrients which otherwise would be lost by effluent and uncontrolled fermentation (Vilela, 1998). The DM, WSC and fermentation acids content of elephant grass silage was increased whilst pH was reduced with the use 0, 5, 10, 15, and 20% of dried citrus pulp (Faria *et al.* 1972). Levels up to 30% of dried ground citrus pulp were added to a 75 days regrowth of

elephant grass resulting in silages with a corresponding linear increase of DM content ($y = 0.49x + 24.0$), a pH in a range from 3.49 to 3.68 and a linear decrease of ammonia-N (Evangelista *et al.* 1996).

4. Formic acid and/or formaldehyde treatments

Commercial formic acid (85%) has been extensively used for the ensilage of unwilted temperate grasses but is gradually being substituted by biological additives, certainly because it is unsafe in handling and application and corrosive to equipment. Information about the use of such additives on tropical forages is limited to research data and no literature was found reporting farm-scale adoption.

Earlier studies by Boin (1975) with the production of young, high-protein, low WSC and DM elephant grass have shown that a 0.8 % rate of formic acid is needed for a reasonably good silage fermentation, while Vilela (1984) found no effectiveness based on silage composition when applying formic acid at various rates to unwilted or wilted elephant grass. On the other hand 0.5% formic acid treated elephant grass had not only an improved fermentation but also higher intake and digestibility as compared to the untreated control (Silveira *et al.* 1980).

King grass (*Pennisetum purpureum* x *Pennisetum typhoides*) silage treated with formic acid (3.5 l/t) showed better fermentation quality than benzoic acid treated and untreated silages (Ojeda and Cáceres 1984). In a review by Ojeda (1993) on the use of mineral or organic acids as well as of antimicrobials it is concluded that for the ensilage of tropical forages kind of additive and application rate need to be determined specifically according to the type of forage.

Formalin (35-40% formaldehyde solution) has also been used as a silage preservative, especially aiming at reduced protein degradation in the silo and thus increasing undegradable protein in the rumen of silage-fed animals. Formaldehyde restricts considerably fermentation of silage; 0.8% formalin (w/w fresh basis) almost sterilizes the ensiled mass of elephant grass and reduces digestibility of silage (Boin 1975). A dosis of 0.5% formalin (w/w) applied to a mixture of elephant grass with cassava tops (20.3% DM, 8.5 % WSC) reduced ammonia-N and increased precipitable protein in silage, however without suppressing a clostridial fermentation (Zanotelli and Mühlbach 198). Studies with a 70% formalin plus 26% formic acid plus 4% water mixture applied 0.2 % (w/w) to elephant grass (13% DM) aiming at a rate of 4 g formaldehyde/100 g crude protein in forage resulted in poor fermentation quality and impairment of nutritive value of silages produced (Lavezzo 1993). Accurate formaldehyde rates necessary to improve fermentation in the silo as well as to obtain a protein protection effect in the rumen are difficult to achieve especially under farm-scale conditions (Mühlbach and Kaufmann 1979).

5. Other additives

Salt – The addition of 1% sodium chloride to a mixture of wilted elephant grass and cassava tops (28% DM, 9.5% WSC) was not effective to improve fermentation of silage as compared to the unwilted control (Zanotelli and Mühlbach 1989).

NPN additives – Such additives as particularly urea when added to high dry matter, low buffering forages (maize or

sorghum grain) increase crude protein content and are claimed to improve aerobic stability of silage at feedout. In a review by Lavezzo (1993) on the use of urea as a silage additive for elephant grass it was concluded that with low DM forage and in the absence of additives rich in WSC such type of product should not be recommended when aiming an improvement of fermentation. Generally, pH value, ammonia-N and acetic and butyric acid contents are increased. Singh *et al.* (1996) registered the highest pH values and ammonia-N levels associated to higher anaerobic proteolytic bacterial populations in *Sorghum bicolor* silages (34 % DM) made with 0.5 % urea. Other NPN sources as ammonium sulfate and biuret, either alone or associated with urea, calcium carbonate or starch sources have also been tested on their effects on silage fermentation, digestibility and intake. The results as reviewed by Vilela (1984) do not favour their use as silage additives either. According to Bolsen (1999), NPN always acts as a buffer during fermentation, requiring extra lactic acid to be produced to lower the pH enough for preservation, thus increasing DM loss.

Poultry litter – This waste product cannot be considered as a typical ensilage additive but has been mixed with easily fermentable forages as a way to increase crude protein content and to eliminate potential pathogens in litter through fermentation (Al-Rokayan *et al.* 1998; Rasool *et al.* 1998; Fontenot and Jurubescu 1980). It can also be used to increase DM content of the ensilage of elephant grass (Lavezzo 1993). It may present high protein together with a high ash content, which increases buffering capacity and may negatively affect fermentation. Almeida *et al.* (1986) ensiled elephant grass (20.3 % DM, 7.9 % WSC) together with 15 % sugarcane and 5 % broiler litter producing a silage of

good fermentation quality; however the mixture with solely 10% litter produced silages with very high butyric acid content (2.36% of DM) and ammonia-N.

6. Conclusions and recommendations

Biological additives– when applied to higher quality tropical forages more suitable to ensilage, such as forage sorghum, fermentation is improved and in silo losses are reduced , however, silages are more liable to aerobic deterioration demanding a good feed-out management particularly with large silos.

With good quality (early growth stage) tropical pasture forages, which lends itself to fast wilting, both treatments wilting and biological additive (inoculant alone or in combination with an effectively proven enzyme mixture) can be recommended. Products so far tested, particularly with the ensilage of the thick-stemmed *Pennisetum* species, do not show consistent positive results regarding fermentation characteristics of silages. More field-scale research is needed to test additive effect on nutrient recovery with silage stored in small well-sealed plastic silos as might be realisable with smallholders. Biological additives are generally available as powders or granules which need to be applied mixed with water to allow a proper mixing with the forage. Sprinkling homogeneously with a watering can could be an alternative under smallholder conditions to spraying with a metered liquid sprayer.

High quality feeds and by-products – are so far the best option as additives for the hard-to-ensile forages such as the thick-

stemmed *Pennisetum* and *Panicum* species. They may be relatively expensive, but cost-effectiveness should always consider the improvement in nutritive value of the ensiled forage. Molasses would be more adequate for wilted or higher DM (>25%) materials, while starch sources could be used alone but also combined with molasses for the ensilage of low DM, unwilted forages. Locally available and cost-effective absorbents such as dried citrus pulp can also be a good alternative.

Additives with restricted use - Formic acid can improve fermentation but most probably will not be cost-effective and realisable under smallholder conditions. More tests would be needed with other acids to determine dosage according to the type of forage. Formalin could be cheaper but results with the ensilage of tropical forages are inconsistent. NPN products are not the choice additives for low DM, low WSC forages; they could be used with wilted forage, preferably in combination with a readily fermentable substrate such as molasses.

7. References

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