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Improved efficiency of sugarcane ensiling for ruminant supplementation

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Introduction

Sugarcane is among the main Brazilian agricultural products. It is estimated that by the year 2012 the country will be producing around 685 million tons in nine million ha (Agrarian, 2007), destined to alcohol and sugar production. Also, the use of sugarcane as forage for dairy and beef cattle in Brazil is increasing, becoming popular among traditional users of corn and sorghum silages.

The main advantage of sugarcane as forage for cattle is its high productivity of biomass production (over 100 t/ha) which results

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in low cost per unit of dry matter (DM), and high energy production per unit of area (15 a 20 t TDN/ha). Also, sugarcane maturation occurs in the same period as forage shortage in pastures. And the technology generated by the alcohol and sugar industry permits agronomical improvement in the production of this forage, in different environments.

Popularization of sugarcane among cattle farmers is due to studies of research and extension sectors that search for solutions to enhance the use of this forage. Among recent progresses, the selection of varieties for ruminant feed, the development of processes to enhance product quality and the use of additives to reduce losses in the sugarcane ensiling process.

Although sugarcane is most commonly used fresh, daily cut and chopped before provided to animals, sugarcane ensiling permits enhancing the activities on the farm and reducing the daily need for labor force, and time spent with feeding. This option has been used especially in large herds.

Due to ensiling, reduction of DM voluntary intake and decrease of nutritive value of sugarcane, are discussed by many researchers, being this effect caused by the typical alcoholic fermentation of yeasts (Pedroso et al., 2005).

In non controlled fermentation conditions (absence of additives), the pool of sugarcane water soluble carbohydrates, especially sucrose, is converted into ethanol, with losses of two CO₂ molecules for each fermented glucose molecule. This type of fermentation, characteristic of this species of forage, results in high DM losses in the form of gas, over 30% of initial DM, according to several authors (Pedroso, 2003; Sousa, 2006). The biochemical equation of ethanol production catalyzed by the fermentative pathway of yeasts can be described as:



Experiments in large scaled silos (Pedroso et al., 2006; Schmidt, 2006) have evidenced low recovery of the produced ethanol, probably due to fast volatilization of this component, which increases DM and forage energy losses. In addition, Schmidt's (2006) evaluation of feedlot beef cattle intake behavior evidenced inhibition of

voluntary intake of silages with higher content of ethanol, with stronger effect in the first six hours after animal were feed.

The use of additives aims to reduce losses, elevate nutritive value or improve the aerobic stability of the final product. Kung Jr. (2000) affirms that in the ensiling process, additives have been used as a way to elevate nutrient and energy recovery in the preserved forage, with a consequent improvement in animal performance. Many factors can interfere in the efficiency of additive use in forages such as, characteristics of the used species, humidity content, mass temperature and pH, content of soluble carbohydrates and epiphytic microorganism population.

As any other technology, the use of additives in forage must be evaluated based on cost and economical profit in the final product. According to Weiss (1996), the cost of an additive, the equipment and labor force necessary for its application are easy to determine; however, the benefits, or investment are difficult to measure. Also, it is difficult to understand when comparing results of an application of a same additive, in the same forage species, in different trials, due to the variability of the obtained results.

In this report, the role of chemical and microbial additives in fresh or ensiled sugarcane conservation will be discussed, based on updated data presented in our previous report (Schmidt, 2008).

Additives and sugarcane composition

The use of additives in sugarcane ensiling aims to inhibit the growth or reduce the activity of epiphytic yeasts that produce alcoholic fermentation during the process. Therefore, a reduction of DM losses, that often overcome 30%, is expected. According to Balieiro Neto et al. (2009), these losses can represent approximately 53 kg of TDN per ton of ensiled sugarcane.

Although many additives tested for these purposes seem to have a beneficial effect on qualitative characteristics of ensiled sugarcane, comparison of the magnitude of additive response, in different trials, is made more difficult by the low consistency and large variability of the results. Probably part of these differences in the result pattern are related to differences in the chemical compo-

sition of sugarcane used in experiments which alter the population and growth rate of epiphytic microorganisms, therefore influencing the additive effects. As an aggravating factor for result comparison, few studies present the complete chemical composition of sugarcane, especially regarding the content of sucrose or total soluble carbohydrates.

An idea of the variability in sugarcane chemical composition was presented by Nussio et al. (2006) based on samples of sugarcane forage sent to the Ruminant Nutrition Lab USP/ESALQ (Table 1).

The large variation in the component contents listed in Table 1 can be due to factors such as sugarcane maturity (Fernandes et al., 2003), variety used (Rodriguez et al., 2006) and other soil, environment and management factors.

Therefore the effects of additives applied on sugarcane must be evaluated in trial groups, outlining response trendy lines, respecting the natural data variability already mentioned. It is important to remember that the reliability of tendencies depends directly on the number of available evaluations (n), being of the scientific community the responsibility to expand data about sugarcane additives.

According to Lovatto et al. (2007), the transformation of research results into usable knowledge requires dozens or even hundreds of experiments and that, in traditional reports, such as this present one, differences in experimental conditions among studies are ignored. The authors suggest the use of Meta-analysis to obtain a more precise estimative of a treatment effect, if the value of "n" is not low. This methodology was used by Kleinschmit e Kung Jr. (2006), who applied Meta-analysis to evaluate the effect of the L.

Table 1. Chemical composition and variation range of sugarcane samples, 2000 - 2006.

Item	n	average	minimum	maximum
Dry mater (%)	21	27,7	20,4	33,9
Non-nitrogen extractive (% DM)	26	68,0	53,3	75,5
TDN estimate (%)	26	64,5	53,9	69,5
NDF (% DM)	23	47,3	37,9	63,9

Source: Adapted from Nussio et al. (2006)

buchneri bacterial additive in corn silage and other grasses, using data from 43 experiments, with different doses of additive.

Additives in sugarcane ensiling

Studies on sugarcane ensiling in Brazil started in the end of the 90s and has been of great interest of researchers from several institutions ever since (Figure 1). Almost all studies published evaluate some kind of additive related to ensiling process. However there is still much to clarify about fermentative dynamic and the role of additives in the conservation of this forage.

The experience, to this present day, allows affirming that the use of additives that control metabolic activity in yeasts is required in sugarcane ensiling. However the type and dose of the "ideal" additive for ensiling of this forage is still questionable due to the variations in the response patterns verified in different trials.

Main additives

A large diversity of additives has been tested in sugarcane ensiling as a way to preserve nutritive value of the preserved forage.

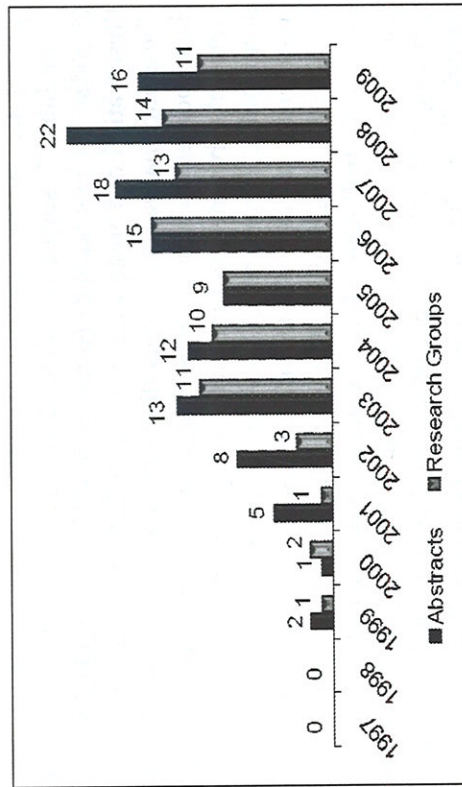


Figure 1. Number of abstracts and research groups working with sugarcane silage, published on the Proceedings of Annual Meeting of Brazilian Society of Animal Science, 1997 - 2009.

In many cases, applying certain additives to sugarcane is based on positive results verified in silages of other forage crops. Also, the experience and intuition of Brazilian researchers, the availability and cost of chemical products used as additives and the partnership with companies that produce microbial additives has aimed researches to look for products capable of blocking alcoholic fermentation inside the silo and guaranteeing good aerobic stability in post-opening.

Among the main additives tested to this present day, we can highlight the chemical ones: urea, Sodium hydroxid (NaOH), sodium benzoate, lime; and the microbial, composed by heterolactic bacteria (especially *Lactobacillus buchneri*) and homolactic bacteria (especially *L. plantarum*). In addition, the association of additives has been tested in order to obtain complementary effects.

Most trials evaluate additive response in relation to silage without additives (control). However, there are cases where the silage without additives behaves in an unexpected way, with low yeast activity and reduced fermentative losses, annulling possible positive additive results.

Factors such as sugarcane variety, maturity, cut season, weather, among others, have effect over epiphytic microorganism population, influencing the magnitude of response to determined additive.

In Table 2, sugarcane silage data obtained by the *Equipe de Qualidade e Conservação de Forragens da USP-ESALQ* (Quality and Preservation of Forage Group from USP-ESALQ) are presented. The group analysis of the trials allows visualizing the variability in the responses of control silages, due to factors that are not contemplated in experiment outline. In three experiments of feedlot cattle performance, control silage provided moderate weight gain rates, considering that in two of the trials (Pedroso, 2003; Schmidt, 2006) the additive silages resulted in a significantly higher weight gain than the control silage. However, in one of the trials developed by Mari (2008), the diet containing control silage provided a higher gain weight than the average of treated silages. In trials of experimental silos, under the same execution conditions, total DM losses in silages without additives vary between really reduced values (Pedroso, 2003; Mari, 2008) to really elevated ones (Souza, 2006; Queiroz, 2006; Santos, 2007).

Table 2. Comparison of control versus treated sugarcane silages on animal performance and total DM losses.

Author	Month/Year	Average daily gain ¹ (kg/day)	
		Control	Treated
Pedroso (2003)	Oct/02	0,94	1,14
Schmidt (2006)	Oct/02	0,82	1,00
Mari (2008)	Sep/04	0,88	0,88
Mari (2008)	Sep/05	1,16	1,03
Author	Month/Year	Total DM losses ² (%)	
		Control	Treated
Pedroso (2003)	Aug/01	18,2	13,4
Pedroso (2003)	Jul/02	6,1	6,4
Junqueira (2006)	Sep/03	22,7	16,2
Souza (2006)	Sep/04	32,5	27,9
Queiroz (2006)	Jul/05	31,4	29,2
Mari (2008)	Sep/05	6,7	10,7
Santos (2007)	Oct/05	34,3	23,9
Muñoz-Maldonado (2007)	Jul/06	15,7	20,7

1. Beef Cattle Feedlot. Silage control or treated were the only variation among diets.

2. Total DM losses evaluated in experimental silos.

As mentioned before, the interpretation of results of additive application requires a group evaluation of available data to determine response tendencies, respecting natural variability of data.

Urea

Applying urea as an additive in sugarcane ensiling has been usual, due to its availability, solubility in water (easy to apply) and correction of silage nitrogen content. The start of yeast population inhibition with the addition of urea is related to the formation of ammonia in the urea degradation reaction, ammonia being a strong inhibitor of microorganisms, through mechanisms that are not well known (Palkova et al., 1997).

The doses of urea often used vary between 0.5 and 1.0% of organic matter (OM), although there are studies evaluating higher doses, up to 8.0% of OM (Ítavo et al., 2004). Most studies used urea diluted in water between 30 and 40 liters per ton of OM. The sum-

mary of the main results obtained to this present day is presented in Figure 2. Studies that evaluated only chemical composition and/or pH of silages were not included.

Thirteen studies evaluated DM fermentative losses in sugarcane silages added with urea. In eight studies a positive effect regarding loss reduction, which was in average of 5.9 percent units, was noticed. The highest loss reduction regarding application urea was verified by Pedroso (2003), 18.6% in control silage to 7.6% in silage with 1% of urea in the DM. However, this was the only author to verify, in another trial, a negative effect of a 0.5% dose of urea in OM, elevated losses from 6.8% to 12.6% in DM.

In eight out of nine studies evaluated, the effect of urea over effluent production was not verified and in only one trial urea evaluated these losses from 15.1 to 32.2 kg/t OM (Pedroso, 2003).

The ethanol content in silages was evaluated in 11 trials and only in four of them the addition of urea was effective in reducing the production of this component, presenting no effect on the others.

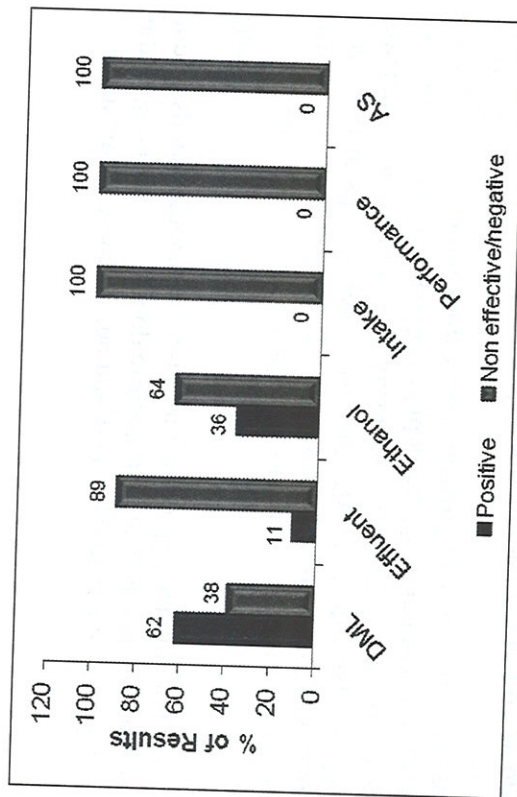


Figure 2. Results of published papers evaluating Urea on sugarcane ensiling, over the variables: Dry Matter Losses (n=13); Effluent production (n=9); Ethanol content (n=11); DM intake (n=6); Performance of cattle (n=2) and Aerobic stability of silages (n=6).

Six studies evaluated the DM intake of ruminants and two evaluated the gain weight of heifers (Pedroso, 2003; Junqueira, 2006). In none of these studies there was an effect of urea addition over these variables, in relation to control silage. In none of the six studies that evaluated aerobic stability of silages with additives, urea was effective in enhancing this variable.

► Discussion

In studies which evaluated the contents of urea addition in sugarcane ensiling (Pedroso, 2003; Siqueira et al., 2004; Roth et al., 2005; Junqueira, 2006), no benefit in using contents higher than 1%, over variables of DM losses or ethanol content was noticed. As discussed by Nussio et al. (2006), the average content of ammoniacal nitrogen in silages with urea additive is low, indicating reduced conversion of urea into ammonia, which limits the efficiency in the use of this additive.

The tendency to elevate effluent production due to application of urea mentioned by Nussio et al. (2003) is not confirmed by the data available to this present day, except those of studies where effluent in control silage was shown to be much reduced.

The benefits of easy access and usage, and improvement in the protein content of silage must be evaluated regarding moderate safety in preventing fermentative losses and silo panel losses.

Sodium benzoate

The dissociation of sodium benzoate during sugarcane ensiling produces benzoic acid, an antimicrobial agent with inhibiting action over yeasts and mold (Woolford, 1975). Benzoic acid is permeable to cellular membranes of yeasts, making the entrance of protons into the cell easier, which leads to internal pH reduction in more than one unit and induces yeast to waste energy in order to balance pH (Krebs et al., 1983).

The application of sodium benzoate was evaluated in eight experimental trials with sugarcane, in doses varying from 0.05 to 0.2% of OM; in six of these trials the used dose was of 0.1%. Additive cost estimative by Nussio e Schmidt (2004) indicates that doses over 0.1% can be economically impracticable. In all trials the prod-

uct was applied diluted in water, in doses varying from 4.5 to 15 liters per ton of OM.

In four out of five studies that evaluated soluble carbohydrate (CHO) content in silages, this fraction was higher with the application of sodium benzoate. Evaluating chemical and microbial additives in sugarcane ensiling, Schmidt (2006) observed that sodium benzoate was the most efficient additive in preserving the CHO fraction of silages, in relation to original sugarcane.

The total loss of DM was evaluated in six studies, presenting two positive results, one negative result and no verifies effect in three studies. In Siqueira et al. (2007), the addition of sodium benzoate reduced in 7.3 percent units the loss of DM. In two of the four trials that evaluated effluent production, this variable was elevated by the addition of sodium benzoate and in the other two there was no effect. However, the variation magnitude was small and of non concern for none of the trials.

Six trials evaluated the ethanol content of silages with sodium benzoate additive, and in none of them this variable was affected by the additive. However, in two trials the ensiling was done on large scale silos, what results in low detection of the ethanol produced, as evidenced by Schmidt (2006). In addition, it was not possible to verify a positive effect of sodium benzoate addition on both trials that evaluated aerobic stability in silages.

Two trials evaluated the DM intake of cattle and one evaluated the weight gain of heifers, fed with a sugarcane silage diet. In none of the trials there were statistic differences due to sodium benzoate over these variables, although daily average weight gain of heifers in the Pedroso et al. (2006) trial was 200 grams higher in silages with sodium benzoate additive than in control silage.

► Discussion

The number of studies that evaluated sodium benzoate in sugarcane ensiling is small, making better interpretations impossible. Only one trial evaluated cattle performance, obtaining highly satisfactory results. In trials were there was no effect of this additive over the DM losses, none of the other additives tested were efficient, due to the reduced level of losses in control silage, what shows feasibility in the use of this additive (Figure 3).

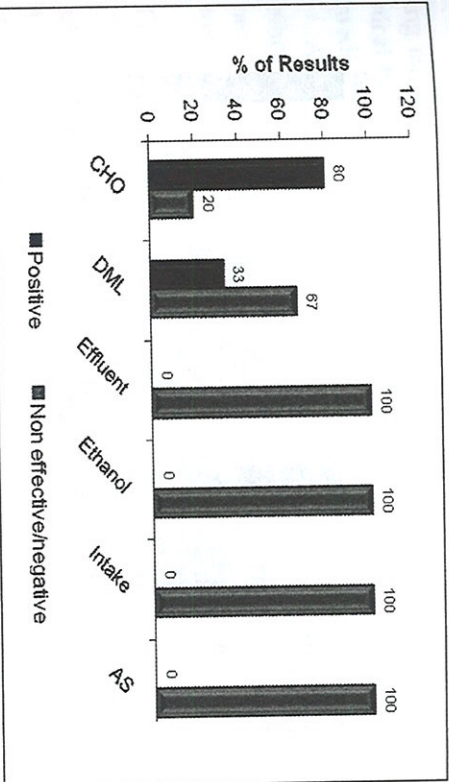


Figure 3. Results of published papers evaluating Sodium benzoate on sugarcane ensiling, over the variables: Soluble carbohydrates content (n=5); Dry matter losses (n=6); Effluent production (n=4); Ethanol content (n=6); DM intake (n=2) and Aerobic stability of silages (n=2).

The use of sodium benzoate as an additive remains restricted to research, due to the difficulty of obtaining such product and lack of more conclusive results. In the last two years, research has not progressed in understanding the effect of this product in sugarcane ensiling.

Sodium hydroxide (NaOH)

Few studies have evaluated the use of Sodium hydroxide (NaOH) as an additive in sugarcane ensiling, based on positive results of this product in hydrolytic treatment of fresh sugarcane. The ensiling trials carried out used doses varying between 0.25% to 4% of OM, commercial products with concentrations of 33, 40 or 50%. The main results obtained are presented in Figure 4.

The use of NaOH in ensiling was effective in reducing DM losses in three of four trials that evaluated this variable; in one of the remaining trials there was a numerical tendency of loss reduction. In average this variable was reduced in 7.1 percent units. A reduction in effluent production was verified in the three trials that eval-

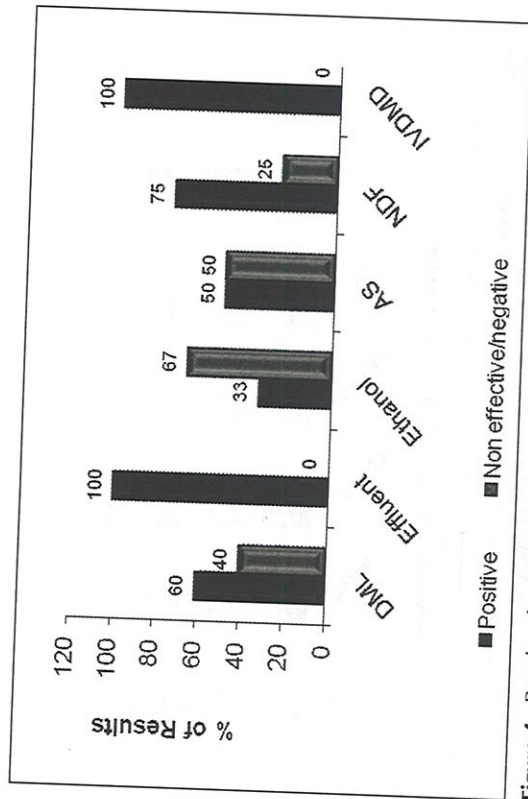


Figure 4. Results of published papers evaluating Sodium hydroxide on sugarcane ensiling, over the variables: Dry Matter losses (n=5); Effluent production (n=3); Ethanol content (n=3); Aerobic stability of silages (n=2); NDF content (n=4) and *In vitro* DM digestibility (n=3).

uated this variable, highlighting Siqueira et al. (2007) who verifies reduction of 76.2 (control) to 3.2kg/t OM (NaOH 1%).

Three studies measured the ethanol content of silages, and only Borgatti et al. (2008) verified a significant reduction, 15.3% in control silage to 1.57% in silage with 1% NaOH additive.

The evaluation of aerobic stability of silages showed antagonistic effects, with strong increase observed by Pedroso (2003) and tendency of stability reduction due to additives mentioned by Siqueira et al. (2007).

Fairly consistent results were evidenced for the NDF content and the *in vitro* dry matter digestibility, with marked effect from NaOH in the reduction of these variables. NDF was reduced in average 6.0 percent units and IVDMD was elevated in 15.6 percent units.

► Discussion

Few studies evaluated the addition of NaOH in sugarcane ensiling, resulting in quite limited “n” value. Trials with animals us-

ing sugarcane silages with this additive were not found in technical literature. However, good results seem to be obtained with medium doses, around 1% of OM.

Although little information apparently shows technical feasibility in the use of NaOH, there is low interest of researchers in new studies with this additive due to safety, economical and environmental limitations (Berger et al., 1994).

Calcium oxide

The use of calcium oxide (lime) as an additive for sugarcane ensiling is a new and growing technology, with 20 publications and a large number of research studies in progress. The first studies on the subject were recently published (Oliveira et al., 2004; Balieiro Neto et al., 2005) and interested the scientific community due to the results. The advantages in the use of lime as an additive is related to its low cost, effectiveness in reducing fermentative losses and possibility of fiber fraction hydrolyze.

The doses tested in trials vary between 0.5% and 2.0% of DM, applied as dry powder or diluted in water (20 to 40 L/t DM). The summary of the main results obtained is represented in Figure 5.

The application of calcium oxide in the moment at ensiling reduced the fermentative DM losses in nine out of the thirteen trials evaluated. There was an average reduction of 11.3 percent units in total DM losses values, highlighting the data obtained by Roth et al. (2006), that verified reduction of 38.7 (control) to 19.3% (CaO 1%). Only Mari (2008) verified elevation of DM losses, in 2.5 percent units.

The production of effluents in silages was reduced in four out of eight trials, the average reduction being of 14.8 kg/OM. Cavali et al. (2006) tested the doses 0; 0.5; 1.0; 1.5 and 2.0% of CaO and verified linear dose effect in reduction of effluent production.

In six trials the addition of lime was efficient in reducing the ethanol production in silage (average reduction of 6.9 percent units) and only in two trials no effect of lime was verified in this variable.

Hydrolytic activities of lime over the fiber fraction, during sugarcane ensiling, was well characterized in 11 trials that evaluated

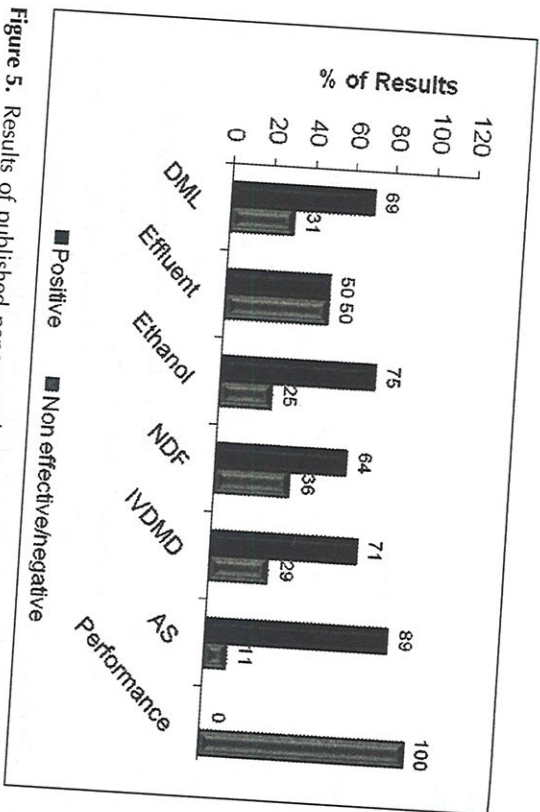


Figure 5. Results of published papers evaluating calcium oxide on sugarcane ensiling, over the variables: Dry Matter Losses (n=13); Effluent production (n=8); Ethanol content (n=8); NDF content (n=11); *In vitro* DM digestibility (n=7); Aerobic stability of silages (n=9) and Performance of ruminants (n=5).

NDF content and in 7 trials that evaluated *in vitro* dry matter digestibility in silages. In seven studies, the NDF content was reduced under lime activity, being that, in average, the additive silages presented 11.2 percent units less in NDF fraction. A similar result was verified for DVIVMS, with increase of 13.7 percent units (average) due to lime application. However, in two studies (Baleiro Neto et al., 2008; Bergamaschini et al., 2008) the lime additive reduced the digestibility of matter in an average of 10.5 percent units. Positive results were obtained in eight out of nine experiments that evaluated aerobic stability of additive silages, which, in average, slowed down heating in 65 hours, in relation to silages with no additives. Santos (2007) verified dose effect over this variable with silages: 1.0 and 1.5% of CaO, respectively.

Five experiments with animals evaluated sugarcane silage with CaO additive, and in none of them a positive effect of animal performance was verified.

Amaral (2007) did not observe effect of silage over the DM intake in dairy goat or sheep. Mari (2008) and Bergamaschini et al. (2008) also did not observe effect of lime addition in ensiling over DM intake of cattle. In addition, the diet containing silage with 1% of CaO provided lower weight gain (0.97 kg/day) than the diet containing control silage (1.16 kg/day).

► Discussion

Lime as an additive in sugarcane ensiling has been widely used in farms, with highly satisfactory results.

Although some variables show linear effect of additive doses (NDF, DVIVMS, effluents, the best results seem to be concentrated in the dose of 1% of OM. Higher content of additives imply in elevation of calcium content in the diet, reaching critical levels as discussed by Schmidt (2008).

The elevation of ash content in silages with CaO additive is noticeable. Santos (2007) verified ash values of 1.75; 6.09 e 7.29% of DM, for control silages, 1.0 and 1.5% of CaO, respectively. Therefore the practical recommendation of calcium oxide content over 1% must be cautious. Regarding application forms, data from Mari (2008) suggest higher effectiveness of calcium oxide diluted in water (40 L/t OM), in relation to applied in dry form.

Research results to this present day have been very positive, with noticeable reduction in DM losses, effluent production and ethanol content, besides marked increase in aerobic stability and DVIVMS. However, the few experiments with animals do not reflect these benefits, making it necessary for new trials to confirm if the results seen in chemical composition of forage translate into performance enhancement.

Lactobacillus plantarum

The bacteria *Lactobacillus plantarum* (LP) is the main agent of the lactic acid bacteria (LAB) group or homolactic bacteria, microorganisms traditionally used as stimulators of fermentation in annual grass, legume and tropical grass ensiling, and that are characterized by the elevated production of lactic acid (Muck e Kung Jr, 1997). Most studies that evaluated the addition of these microor-

ganisms in sugarcane ensiling applied the doses recommended by the manufacturer which is in general between 5×10^5 and 1×10^6 CFU/g wet forage. The main results obtained still this moment are summarized in Figure 6.

In twelve studies that evaluated DM losses during sugarcane ensiling, only one presented reduction of 5.6 percent units (Itavo et al., 2004), due to LP inoculation.

In ten studies higher numerical values were observed for total loss of DM in inoculated silages, in relation to control silages, and in Junges et al. (2009), the inoculation with LP elevated the losses of DM in 12.8 percent units.

Only one out of seven studies that evaluated effluent production in silages verified beneficial effects of this additive (Pedroso, 2003).

Of the ten studies that evaluated ethanol content in silages, five did not present LP inoculation effect, and in the other five the ad-

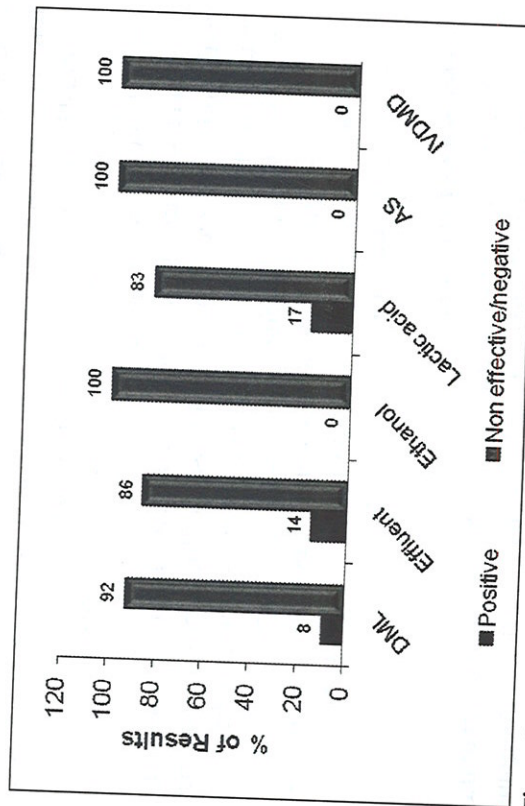


Figure 6. Results of published papers evaluating inoculation of *Lactobacillus plantarum* on sugarcane ensiling, over the variables: Dry Matter Losses (n=12); Effluent production (n=7); Ethanol content (n=10); Lactic acid content (n=6); Aerobic stability of silages (n=6) and *In vitro* DM digestibility (n=11).

ditive elevated the ethanol content in silages (% of DM), in relation to control (Pedroso, 2003; Castro Neto, 2003; Pedroso et al., 2007; Bergamaschine et al., 2008; Junges et al., 2009).

The lactic acid content in silage was elevated by the addition of LP in only one (Junges et al., 2009) of the six trials that evaluated this component, although Castro Neto (2003), Freitas et al. (2006a) and Muñoz-Maldonado (2007) had observed low numerical elevation in this variable.

In six trials that evaluated aerobic stability in silages, five did not present significant additive effect, and one trial verifies stability reduction (Pedroso, 2003) due to LP inoculation.

The *in vitro* DM digestibility analyses of LP inoculated silages was carried out in 11 trials; in nine there were no significant treatment effects, and in two the LP inoculation reduced the DVIVMS. The average values observed for digestibility were 46.4% of DM for silages without additives, and 45.8% for silages with LP additive.

► Discussion

The analysis of the studies shows the inefficiency of lactic acid bacteria in altering the fermentative pattern of sugarcane. The negative results obtained are probably due to the fact of yeasts not being efficiently inhibited by lactic acid (Moon, 1983; Danner et al., 2003) and use this acid as a substrate for ethanol production (McDonald et al., 1991), stimulating fermentative losses of DM.

Only one trial (Freitas et al., 2006b) evaluated levels of inclusion above manufacturer recommendations, without verifying elevation effect of 20 and 40% in doses, over the evaluated variables.

The lack of response in lactic acid content of LP inoculated silages, in almost all trials, can be related to the fast development of epiphytic microorganisms in sugarcane, due to high content of soluble sugar in this forage. Data from Pedroso (2003) show pH stability of silages without additives on the third day after ensiling, and confirm that, in sugarcane silages, the pH value does not indicate fermentative quality (Schmidt, 2006). The values detected in lab analysis show only the punctual content of lactic acid in sample harvesting, not considering that part of the lactic acid produced could have been metabolized by other microorganisms.

As mentioned for other additives, trials of animal performance using LB inoculated sugarcane silage were not found in literature. The use of additives containing LAB for sugarcane ensiling in farms is very common and it is related to the commercial opportunity and lack of technical knowledge of the inefficiency of this product.

Lactobacillus buchneri

The bacteria *L. buchneri* (LB) is an agent in the group of Heterolactic bacteria, microorganisms that produce significant quantities of other organic acids such as the acetic and propionic, besides lactic acid.

Moon (1983) affirms that the acetic acid is and acknowledged inhibitor agent of yeast growth, and according to Danner et al. (2003), the antimicrobial effect of an organic acid depends of its pKa and of the environment pH. The lactic acid has lower pH than the acetic acid making it stronger for this reason. However, in the pH range normally found in silages, the acetic acid is less dissociated than the lactic acid, allowing it to penetrate the plasma membrane of yeast, inactivating them.

Inoculation with LB in sugarcane ensiling was first suggested by Nussio et al. (2003), base done positive results of yeast population control in corn silages (Driehuis et al., 1999). In Figure 7 the main results of studies which evaluated this additive in sugarcane are shown.

Of 31 experiments evaluated, 27 used the LB dose recommended by manufacturers, of 5×10^6 CFU/g wet forage. Only the initial trials of Pedroso (2003) and Schmidt (2006) worked with a $3,6 \times 10^5$ CFU/g wet forage dose.

Of the 19 trials that evaluated fermentative losses of DM, the LB inoculation was capable of reducing them to eight. In 9 trials, treatment effect was not verified, and Mari (2008) and Junges (2009) observed elevation in DM losses in LB inoculated silage. In average, the values of fermentative loss of DM were $26.7\% \pm 10.7$ for silages without additive and $23.0\% \pm 11.4$ for silages with LB additive.

The production of effluents in experimental silos was evaluated in 16 trials, presenting no treatment effect in 13 trials. The values

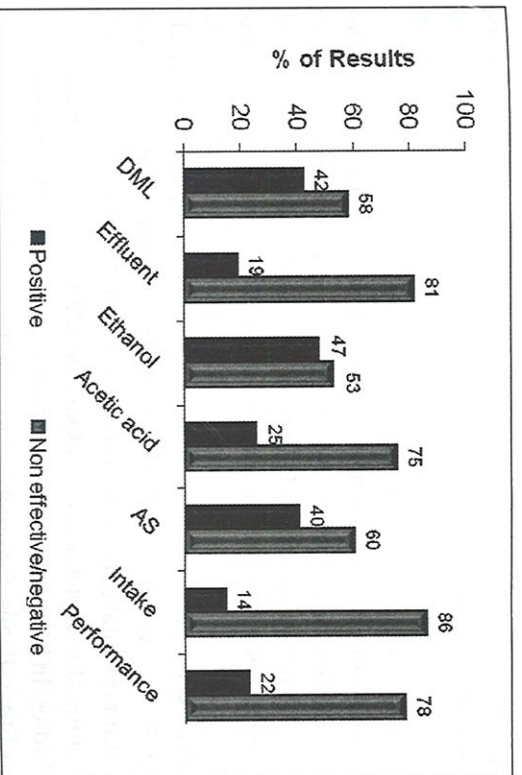


Figure 7. Results of published papers evaluating inoculation of *Lactobacillus buchneri* on sugarcane ensiling, over the variables: Dry Matter Losses (n=19); Effluent production (n=16); Ethanol content (n=19); Acetic acid content (n=12); Aerobic stability of silages (n=15); DM Intake by ruminants (n=14) and performance of ruminants (n=9).

observed vary between 6.0 a 95.9 L/t OM, however without showing themselves critical or excessive. The LB inoculated silages presented average production of 38.3 ± 19.9 L/t OM.

The ethanol content was reduced by the LB inoculation in nine of the 19 trials which evaluated this component. In average, the inoculation with LB reduced 2,9 percent units in the ethanol content, in relation to silage control, which presented average content of 6.7% of DM.

Only three among 12 trials verified significant elevation in the acetic acid content of LB inoculated silages, in relation to control. The average content of this acid for silages without additive and LB inoculated silages were 3.19 and 3.77% of DM, respectively.

Aerobic stability of silages inoculated with *L. buchneri* was evaluated in 15 studies. In six studies the bacteria was effective in significantly elevating stability, and in other five studies there was a numerical tendency of elevation. The average time for temperature

elevation of 2°C in silages was of 49 ± 15 hours and 63 ± 23 hours, for control silages and LB inoculated silages, respectively. For inoculated silages the longest stability time was 106 hours, verified by Mari (2008) and the shortest was 35 hours (Santos, 2007).

Ten authors carried out trials with animals, evaluating metabolism, milk production and weight gain. Fourteen studies evaluated the DM intake of goats (Mendes, 2006), lambs (Gentil, 2006), dairy heifers (Pedroso, 2003; Junqueira, 2006), dairy cows (Queiroz, 2006; Azevedo et al., 2007; Pedroso et al., 2009) and beef cattle (Schmidt, 2006; Mari, 2008; Balieiro Neto et al., 2008; Bergamaschini et al., 2008). Twelve trials did not verify effect of the silage type over voluntary intake, and the inoculation with LB was effective in evaluating this variable only in Queiroz (2006) and Junqueira (2006) studies. In both studies the comparison was made in the remaining additive silages, for not evaluating silages without additives.

The performance of animals which intake diets containing silage of sugarcane inoculated with *L. buchneri* was evaluated in nine trials. Only two initial trials verified positive effects of inoculation. Pedroso (2003) observed increase of 0.3 kg in daily weight gain of Holstein heifers, in relation to control silage (0.94 × 1.24 kg/day). Schmidt (2006) observed elevation of 0.18 kg/day in weight gain of Nelore and Canchim beef cattle, due to inoculation with LB in ensiling.

► Discussion

The bacteria *L. buchneri* is the inoculant for sugarcane with the largest number of information available, probably due to good results obtained in initial researches (Pedroso, 2003; Schmidt, 2006). However, animal performance trials carried out afterwards do not confirm these results for unknown reasons.

The variability in response patterns of this inoculant seems to be superior to those of other additives. Possibly, this effect occurs as we are dealing with live microorganisms, which depend on a great number of factors for a good development. The elevated variation coefficient inside the same trial reduces the possibility of an additive to show significant differences in relation to another additive. This effect is well marked for the "aerobic stability" variable.

The verified results in acetic acid content and aerobic stability differ from observations made by Kleinschmit and Kung Jr. (2006), who observed significant increase of LB additive over these variables, in an average of 43 trials with corn and grass silages.

New investigations, including on factors that determine high variability in responses of sugarcane silages to LB inoculation, are necessary to confirm the potential of controlling ethanolic fermentation and increase in nutritive values of silages shown in some trials. The strains of LB and the doses commonly inoculated need to be reviewed to assure more consistent results.

Additive association

Several authors have tried to increase the benefits of additives in sugarcane silages, associating products to possible synergic effects. Commercial additives containing different bacterial strains, associated to enzymes or chemical products have tried to minimize losses and elevate fermentative efficiency in silages.

Siqueira (2005) evaluated the association of chemical additives (urea, sodium benzoate and NaOH) and microbial (LAB and *L. buchneri*) in sugarcane ensiling and verified that the joint additive with LB enhanced the efficiency of chemical additives.

The association of *L. buchneri* and lime was evaluated by Roth et al. (2007) who verified positive results for the variable DM recovery, gas losses and effluent losses under lime addition (1% of OM), independent of inoculation or not with LB.

Muñoz-Maldonado (2007) evaluated the association of two microbial additives base don LAB with sodium benzoate, in sugarcane ensiling, without verifying any positive effect of inoculation with microorganisms, exclusive or associated to benzoate.

Recently, Junges et al. (2009) evaluated the association of microorganisms *Lactobacillus brevis*, *Enterococcus faecium* and *L. plantarum* in sugarcane ensiling, and verified prevailing lactic fermentation, with no benefits over the losses and stability of silages.

Although technically interesting, the association effects of different additives are not necessarily complementary, being able to elevate the variability in response patterns and making it even

harder to comprehend obtained results. However, the use of two associated additives implies in elevating costs and logistic demands inside the farm, which limits its practical terms use.

Implications

The responses top additive use in ensiling present great variability due to non contemplated effects in experimental models, possibly due to epiphytic microorganisms populations in the material taken to the silo. These variations were observed by other authors (Muck e Kung Jr., 1997), especially when the animal component is analyzed (Kung Jr e Muck, 1997).

The choice for an additive must be done analyzing the total cost of product application and the potential benefit in nutritive value and loss reduction. Available data indicate lime as the best additive option for sugarcane ensiling, although the benefit in animal performance has not yet been proved.

It is up to researchers to continue studies of additive evaluation in sugarcane ensiling, considering fermentation patterns, inherent losses to ensiling process, the mechanism of additive addition and variables of responses in animals.

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Optimization of the animal production system based on the selection of corn cultivars for silage

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Introduction

Originally from the tropics, specifically Mexico and Guatemala, corn belongs to the C4 plants group, and is traditionally the most used plant for silage production. There are several aspects that can contribute for this, such as, high dry matter production, optimum dry matter content at harvesting, at least 3% of soluble carbohydrates on an as-is basis, lower buffering capacity, and besides that, adequate microbial fermentation.

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