Agricultural management of sugarcane fields for silage production

Ricardo Andrade Reis[1], Gustavo Rezende Siqueira[2], Anna Paula de Toledo Piza Roth[3]

1-Professor Titular do Departamento de Zootecnia da UNESP – Campus de Jaboticabal, Bolsista de Produtividade em Pesquisa do CNPq, Membro do INCT E-mail: rareis@fcav.unesp.br;

2-Pesquisador da APTA Regional – Colina-SP, Professor do Programa de Pós-graduação da UNESP – Campus de Jaboticabal; E-mail: siqueiragr@apta.sp.gov.br;

3 – Doutoranda em Zootecnia FCAV/Unesp – Campus de Jaboticabal

1- INTRODUCTION

Sugarcane is considered to be the best bioeconomic forage option for feeding dairy and beef cattle (NUSSIO et al., 2003; RESENDE et al., 2005; SIQUEIRA et al., 2008). However, exceptions do exist, especially in a country the size of Brazil. Many consider the advantages of sugarcane to be countless such as roughage in ruminant feeds. On the other hand, there are several indications that it should not be used as feed for animals with proven genetic potential, since it has inadequate protein and mineral levels as well as low quality fiber. Although concerns regarding the nutritional limitations of sugarcane are real, they should be considered from a different angle.

Producers often overlook aspects related to variety choice, agricultural management, forage harvesting and chopping; consequently, this forage resource is often unsuccessful. Furthermore, general manner of use is another problem. Sugarcane is harvested on a daily basis for animal feed. Logistics can make this task difficult or impossible; consequently, silage has become an alternative.

In order to compare sugarcane with other forages, the diets need to be adjusted for a fair comparison. In studies in which an inadequate change in dietary bulk occurred, the corresponding authors believe that theoretical and practical validations were missing.

This review was prepared to discuss important aspects of agricultural management of sugarcane for silage production.

2- Sugarcane Silage

Sugarcane is rich in soluble sugars, about 23% (PEDROSO et al., 2005), with low buffering capacity 7 e.mg HCl/100 g dry matter (SIQUEIRA et al., 2007a) and adequate dry matter content, ranging from 25 to 35% (BERNARDES et al., 2007, SCHMIDT et al., 2007 and SIQUEIRA et al., 2007b). These characteristics give sugarcane high fermentative capacity.

According to previously cited data, sugarcane could theoretically have intrinsic characteristics that are adequate for ensiling and much superior to other cultures, such as corn, sorghum and tropical grasses. These conditions along with silage management of particle size, compaction and sealing are favorable for development of desired microorganisms, such as *Lactobacillus* and *Pediococcus* genera from homofermentative bacteria. Acid production begins during the anaerobic phase of the ensiling process due to high substrate availability. Together with low buffering capacity, acid production reduces pH quickly. EVANGELISTA et al. (2009) and SIQUEIRA et al. (2011a) observed decreased pH with values below 4 at three days fermentation, which is desirable in the ensiling process of any roughage.

However, sugarcane has an epiphytic microflora rich in yeasts that can reach 1×10^6 ufc/g fresh forage (ROTH et al. 2010, ÁVILA et al., 2010, SIQUEIRA et al., 2011a). Most yeast species need oxygen for growth, because the respiratory pathway presents greater energetic yields. However, some yeast species grow under anaerobic conditions and can maintain large populations under these circumstances due to sugar fermentation (WALKER, 1998). During the sugarcane ensiling process, pH drops quickly and yeast dominate the fermentation process, because they are not inhibited by the reduced pH of the food and are able to grow in pH levels ranging from 2 to 8. This characteristic allows yeast to inhabit different environmental niches compared to bacteria (McDONALD et al., 1991; WALKER, 1998), besides the fact that ethanol, a byproduct of yeast fermentation, is toxic to many microorganisms.

According to McDONALD et al. (1991), CO_2 loss during yeast fermentation is responsible for a 48.9% loss in mass (Equation 1).

$$\text{Glucose} + 2\text{ADP} + 2\text{Pi} \rightarrow 2\ \text{Ethanol} + 2\ CO_2 + 2\ \text{ATP} + 2\ H_2O \qquad \text{Eq.1}$$

Gas loss and consequently recovery of ensiled dry matter are primary concerns in sugarcane silage. The decision to ensile this forage instead of daily harvesting should consider losses inherent to the process, since they inflate the cost of effectively stored dry matter for use.

Despite lower gas loss, effluents are still produced, which can be considered another source of loss. Considering the DM content of an effluent, 6% as suggested by SCHMIDT (2006), effluent loss normally observed in sugarcane silage (15 – 40 kg/t ensiled forage) does not represent more than 1% dry matter.

One of the consequences of dry matter loss is a proportional increase in fibrous constituents, and consequently reduced *in vitro* dry matter digestibility of silage, compared to sugarcane at the time of ensiling (Table 1).

Note that on average for each increase in neutral detergent fiber (NDF), *in vitro* dry matter digestibility decreased 0.83 units. In general, NDF in silage without additives increased 16%, which corresponds to 13.3% digestibility (Table 1).

Sugarcane silage loss should be measured quantitatively and qualitatively. Siqueira et al. (2007b) stated that simplistic evaluation of bromatological characteristics without correcting for quantitative losses may underestimate the true extent of qualitative losses. Seeking a more comprehensive quantification, these authors suggested recovery of digestible dry matter as a variable that comprises quantitative and qualitative concepts of loss during ensiling.

Table 1. Variations in neutral detergent fiber (NDF) and *in vitro* dry matter digestibility (IVDMD) in sugarcane at ensiling and at opening

Source	Fresh forage		Silage		Variation	
	NDF	IVDMD	NDF	IVDMD	NDF	IVDMD
PEDROSO et al. (2005)	49.6	62.9	72.9	45.5	+23.3	-17.4
BALIEIRO NETO et al. (2007)	55.5	66.5	63.3	62.1	+7.8	-4.4
SIQUEIRA et al. (2007b)	52.1	52.6	75.3	35.1	+23.2	-17.5
FERREIRA et al. (2007)	55.3	58.1	69.7	46.5	+14.4	-11.6
SCHMIDT et al. (2007)	55.5	51.3	66.0	41.9	+10.5	-9.4
SANTOS et al. (2008)	52.9	59.0	67.1	48.7	+14.2	-10.3
SOUSA et al. (2008)	48.7	63.6	68.1	50.4	+19.4	-13.2
CAVALI (2006)	44.0	66.9	62.9	48.4	+18.9	-18.5
MALDONADO (2007)	43.9	58.7	55.4	51.9	+11.5	-6.8

Several studies have been conducted regarding the effect of additives on storage loss. The most promising were calcium oxide (BALIEIRO NETO et al., 2007; SANTOS et al., 2008; AMARAL et al., 2009; ROTH et al., 2010, SIQUEIRA et al., 2011b); *Lactobacillus buchneri* (PEDROSO et al., 2007; SIQUEIRA et al., 2007a,b; ÁVILA et al., 2009), sodium benzoate (PEDROSO et al., 2007; SIQUEIRA et al, 2007a,b); urea (PEDROSO et al., 2007;

FERREIRA et al., 2007; LOPES & EVANGELISTA, 2010), calcium carbonate (SANTOS et al., 2008) and moisture sequestrates (BERNARDES et al., 2007; LOPES & EVANGELISTA, 2010).

After a brief background of issues related to sugarcane silage, issues regarding agronomic management will be addressed.

3- AGRICULTURAL ASPECTS

3-1. VARIETY CHOICE

When starting a livestock project that will use sugarcane as roughage, the first decision is variety choice. Culture type has a greater impact on sugarcane than it does on corn and sorghum, because sugarcane is a semi-perennial plant. A leading criterion in determining the feasibility of sugarcane use is field longevity. NUSSIO & PONCHIO (2004) demonstrated through simulations that increased field longevity, about 5 years on average, profoundly reduced the cost per ton of harvested dry matter.

MIGUEL et al. (2011) evaluated different contractual arrangements of sugarcane production and observed that average cost of forming 1 ha for sugar and/or ethanol production in northern São Paulo was U$ 1,766. This high implementation cost needs to be diluted in subsequent cuts. Thus, the choice of suitable varieties is fundamental, since reformulation only occurs after at least 6 years, otherwise, the main advantage of low cost per ton will not be reached.

An example of longevity can be seen in Torres & Costa (2001). These authors managed sugarcane for 10 years while maintaining high production. In the tenth year, they corrected the soil and used organic fertilizer, and again succeeded in raising productivity of the varieties under study. In agricultural ventures, goals for field use are normally set for six years. If these goals are met, the strategy of variety choice is considered a success. In practical terms, greater longevity is desirable but difficult to achieve.

Another fundamental point in variety selection is productivity. SIQUEIRA et al. (2008) argued that the main reason for using sugarcane in animal feeds is its high mass per area unit. Sugarcane productivity (t/ha) should be 2.5 to 3.0 times that obtained with corn for it to be viable in animal feed systems. As a result, varieties with low productivity should be excluded from the production system. In the sugar-alcohol industry, there is a wide range of varieties available that are adapted to diverse edaphoclimatic conditions. It is understandable that productivity of a variety varies greatly depending on environmental conditions. In this way, responsive varieties are more efficient under favorable environmental conditions. On the other hand, more rustic varieties should be used in restrictive environments.

The use of sugarcane in animal feed is questioned because of its low concentration of protein (nitrogen) and minerals. Due to its low crude protein content, sugarcane is frequently reported in the literature as inadequate for use in animals of medium to low production. Conversely, SIQUEIRA et al. (2011c) state in a review on sugarcane in ruminant feed that the greatest competitive advantage of sugarcane is its low nitrogen content. These authors show that among forage types normally used in animal feeds, sugarcane is the most efficient in assimilating biomass depending on the amount of nitrogen applied. According to these authors, this quality, which has always been considered a disadvantage and has often even been recognized as a nutritional limitation, is the main advantage for its use in sugarcane. In the review, they also suggest that the reader estimate the quantity of nitrogen fertilizer needed to produce 30-50 t dry matter sugarcane with a hypothetical value of 10% protein.

It is worth mentioning that sugarcane's low demand for N, related to potential mass production, is due to the system's high efficiency in CO_2 fixation, in other words, participation of the ribulose-1,5 phosphate carboxylase (RUDP) system associated with phosphoenolpyruvate carboxylase (PEP). The greater photosynthetic efficiency of plants that develop a C4 cycle, like sugarcane, facilitate adaptation to high temperatures (35 to 38^{o}C) associated with greater water and nitrogen use efficiency (LONG, 1999; MOSER et al., 2004). The C4 carbon fixation pathway gives plants greater adaptation to environmental factors typical of tropical regions, like central Brazil, where high temperatures and light are recorded.

The real limitation to sugarcane use in animal feed is low digestibility of fibrous fractions. This is caused by the low NDF degradation rate, which according to SILVEIRA et al. (2009) is less than 2%/h, and the high undegradable fractions (NDFu), which are more than 50% NDF (MACEDO et al., 2011). In corn silage, the degradation rate of fibrous fractions is 5%/h and undegradable fractions are less than 30% (PIRES et al., 2010). Increased fibrous fractions lead to rumen fill and consequently reduced voluntary intake.

CORRÊA et al. (2003) noted reduced milk production in Holstein cows fed sugarcane (31.9 kg milk/day) compared to cows fed corn silage (34.4 kg milk/day). These authors attributed this decrease to lower dry matter consumption (1.5 DM/cow/day), possibly caused by the lower NDF digestibility in sugarcane (23.1%) compared to corn silage (42%). Another interesting observation was a reduction in dry matter intake with an extended evaluation period, which was not observed when animals were fed corn silage. This suggests a reduction in passage rate and an increase in total retention time, as observed by MAGALHÃES et al. (2006) in a study to evaluate substitution of corn silage with sugarcane.

In order to determine the genetic variability of sugarcane varieties, CARVALHO et al. (2010) evaluated the effects of fibrous fraction components on digestibility of dry matter and fiber. They found stem NDF to have lower digestibility (11.9%) than leaf (23.9%). Nevertheless, stem NDF content is lower (38.2%) than that of leaves (68.7%). These authors did not consider residues that probably have higher NDF values than leaves. Another interesting observation in this study was that when varieties were harvested at the beginning of the season, the reduced NDF/POL (sucrose value) ratio was vital in increasing dry matter digestibility. However, when sucrose accumulation is higher (September), NDF digestibility has a pronounced effect on dry matter digestibility. Lastly, NDF digestibility was found to be related to the lignin/NDF ratio and not with concentration of lignin, NDF, POL or NDF/POL. According to the authors, this demonstrates that fiber digestibility is related to the quality and not quantity of this fiber.

The fibrous part of sugarcane clearly limits its inclusion in ruminant feed. The search for alternatives to increase the passage rate of sugarcane should be pursued. An alternative is to improve fiber digestibility through genetic breeding programs; however, this cannot be obtained at the expense of production level. Another question to consider is how much digestibility can be improved without overturning the sugarcane field since operational difficulties related to sugarcane harvesting are another obstacle to its use.

As previously mentioned, the main criterion used in variety selection is productivity. An important parameter to consider is yield of digestible dry matter per hectare, since it considers both quantitative and qualitative aspects. A joint analysis of data obtained by ANDRADE et al. (2003) and BONOMO et al. (2009) found that the relationship between digestible matter production/ha is more related to dry matter production than digestibility. Studies of sugarcane cultivars that consider production and nutritional composition, like the two mentioned above, are rare. Variety selection aiming to improve quality cannot be realized at the expense of productivity characteristics. It should be stressed that there are varieties on the market that meet the quantitative and qualitative requirements for use in animal feed.

Few articles evaluate the effect of variety on silage. Schmidt (2006) evaluated the effect of two varieties, IAC86-2480 and IAC87-3184, and found that the latter presented silage with lower gas production and higher dry matter recovery, regardless of the presence or absence of additives and harvesting time. Although variety IAC86-2480 presented higher losses at the opening of the silos, it also presented greater levels of soluble carbohydrates and digestibility. Thus, a joint analysis of quantitative parameters is needed to direct sugarcane for silage, which is represented in the present study by loss and quality after opening the silo.

RODRIGUES et al. (2008) observed large variations in dry matter recovery, from 54.29 to 98.7% (Table 2).

Table 2. Variables evaluated, mean, standard deviation, minimum and maximum values of 50 sugarcane varieties

Variable[1]	Mean	Stand. Deviation	Min	Max
DMs	32.39	1.98	25.66	37.54
DMo	24.99	2.72	17.28	33.68
VDM	7.40	2.46	-0.67	12.43
GAS	17.15	3.04	9.02	23.18
DMR	74.04	6.53	54.29	98.70
pH	3.15	1.22	2.80	3.45
BRIX	21.49	1.42	16.94	24.00
POL	19.99	1.68	14.76	22.77
RS	0.45	0.09	0.33	0.87
PUR	92.88	2.68	80.72	96.64

1-DMs- dry matter in silage, DMo- dry matter at opening, VDM- variation of dry matter, GAS- losses by gas, DMR- dry matter recovery, BRIX- total soluble solid content, POL- Sucrose content, RS- reducing sugars (glucose + fructose) and PUR- purity of juice.

Source: RODRIGUES et al., 2008

The authors' objective was to identify correlations among chemical composition, sugar level, and dry matter loss in silage. However, dry matter recovery was not significantly related to sugar content or type. The authors argue that issues related to epiphytic microflora may have led to the lack of correlations. SILVA et al. (2008) observed a direct effect of soluble carbohydrate content on ethanol content and dry matter loss. These authors estimated the level of soluble carbohydrates to be 12.4% DM for no ethanol production.

However, it should be stressed that the search for varieties or management techniques to reduce the level of soluble carbohydrates at the time of ensiling in order to reduce loss does not seem to make much sense, since the energetic source of sugarcane is soluble carbohydrates. In this sense, the stoichiometric balance of variety choice needs to be calculated with two goals. One aims to reduce loss without affecting the energy level, which can be obtained via soluble sugars. The other aims to reduce the contribution of compounds produced during fermentation, like ethanol.

3.2. HARVESTING TIME

The sugarcane and alcohol sector constantly uses the concept of physiological maturity related to variety. In this way, sugarcane harvesting is always realized when the stalk nears maximum sugar accumulation. Physiological ripeners are often used to increase sugar concentration. The livestock sector rarely uses physiological ripeners and tends to harvest indiscriminately.

FERNANDES et al. (2003) evaluated 10 sugarcane varieties (five early and five intermediate/late) to be used in ruminant feed. These varieties were harvested at 426, 487 and 549 days after planting. Results showed an interaction between Brix (total sugars) and harvesting age. Intermediate/late varieties have higher concentrations of Brix when harvested late. Although no significant differences were found, it is clear that delaying the harvesting period increased the concentration of total sugars in intermediate/late varieties, increasing from 18.0 (426 days) to 22.1 (549 days). On the other hand, early varieties kept close Brix levels, 18.6 and 19.7 at 426 and 549 days, respectively. Based on the varieties studied, the authors concluded that varieties with an intermediate production cycle have better nutritional value than early varieties with lower NDF and ADF values, less total rumen repletion, and greater percentages of TDN and Brix. Nevertheless, these results should be interpreted with caution, since they involve the sugarcane plant (first cut). These authors believe that in subsequent cuts a greater amount of interactions should exist, which justifies use of early varieties at the beginning of the dry period (April and May) and intermediate and late varieties for the remaining dry months.

Comparing ensiled sugarcane at 12 and 24 months regrowth, SANTOS et al. (2006) found the strategy of allowing sugarcane to go from one year to another without harvesting should be omitted in comparisons with first year sugarcane silage. These authors observed significantly greater values of fibrous fractions, NDF and ADF, in both fresh and ensiled sugarcane in response to adoption of this practice.

There is usually an increase in digestibility due to the increased participation of soluble carbohydrates in sugarcane with prolonged maturity. SCHMIDT et al. (2007)

observed this effect in varieties IAC86-2480 and IAC87-3184 when analyzed before ensiling; however, after ensiling this trend was inverted. The authors suggest that this result was due to greater intensity of dry matter loss in silage of plants harvested at 18 months.

A classic study, developed to evaluate the effect of harvesting time on sugarcane silage quality realized by KUNG Jr and STANLEY (1982), shows the increase in nutritive value of the fresh forage and the decrease in *in vivo* dry matter digestibility of silage in response to increased harvesting age. According to the authors, this fact is related to ethanol production during the fermentation process, which resulted in decreased soluble sugar content.

3.3. ROW SPACING

Reduced spacing between rows tends to raise sugarcane productivity (MURARO et al., 2011; GALVANI et al., 1997; BASILE FILHO, 1992). A pioneer study performed by AGUIRRE Jr. & ARRUDA[1] (1954) and cited by BASILE FILHO (1992) evaluated three row spacing (1.00, 1.30, 1.60 and 1.90 m) over five consecutive years, in other words a complete production cycle of a plot. They concluded that smaller spacing produced the greatest number of tillers per area, but did not affect mean stem weight; consequently, productivity increased. On the other hand, BASILE FILHO (1992) observed sugarcane cultivated at 1.0 m spacing compared to 1.45 m reduced tillering per linear meter. However, due to the larger number of linear meters, when the evaluation was realized per area unit, a greater number of tillers were observed as well as greater productivity.

The abovementioned studies were directed toward the sugar-alcohol industry. On the other hand, MURARO et al. (2011) evaluated the effects of reducing row spacing of sugarcane cultures used in animal feeds. Row spacing of 0.90 and 1.30 m were compared using RB72-454 variety, which is a common variety for ruminant feed. Assessment was carried out in the first year crop (cane plant). Sugarcane harvested at 420 days presented an increase from 48.12 to 56.67 t DM/h (17.7%) with reduced spacing. Increased productivity may be attributed to the increased number of tillers per area, since reduced weight of tillers (14.7%) was offset by an increase in number of tillers (35%), since the number of tillers per linear meter was not reduced. Analysis of the bromatological composition of sugarcane produced by adopting these treatments did not present any significant differences in any of the

[1] AGUIRRE JÚNIOR, J. M.; ARRUDA, H.C. Study of sugar cane varieties and spacing. In: CONGRESSO PANAMERICANO DE AGRONOMIA, 2. 1954, Piracicaba. Resumos. Piracicaba, 1954, p.49

parameters analyzed, which shows that productivity gains did not affect quality (MURARO et al., 2009).

Another possibility of exploring reduced spacing is by maintaining the productivity achieved by decreasing the number of seedlings per liner meter and consequently maintaining the number of seedlings per hectare. SIQUEIRA et al. (2011c) suggested that this would be an interesting strategy to facilitate the harvesting using forage harvesters projected to harvest crops like corn and sorghum. In MURARO et al. (2011) and other reviews, the same number of seedlings (13-15 buds) were used in each linear meter. Thus in order to facilitate harvesting, these authors suggested proportionally reducing the number of seedlings to about 10 buds/linear m in planting with 0.9 m row spacing. The practice of reducing row spacing is not much used in the sugar-alcohol sector, due to the increase in furrows and difficulties in mechanical operations because the machine needs to traffic over the planted rows. However, the authors of this text only suggestively believe that the intensity of managing plots for animal feed is less intensive and cause less damage to stumps. Note that with 0.9 m spacing it is possible for equipment to move with two lines between the wheels, but this form of management requires more skilled operators than that required for only one line.

3.4. HARVESTING AND RESIDUE

Almost all of the aerial part (leaves, stalks and husk) of sugarcane is removed during harvesting. When harvesting is manual, the husk and tip, as defined by RIPOLI & RIPOLI (2001) as the apical part of sugarcane stalks formed by internodes in formation covered by sheaths of leaves, can be removed to possibly improve the nutritional value of the forage.

Manual harvesting is performed by operators using machetes or pruning shears to segregate stem from its connection to the root system. Cuts should be made at the stem base, seeking to gather as much forage as possible. This harvesting form is carried out throughout the period of use.

Mechanical harvesting began with the use of harvesting machines for cultures like corn and sorghum. However, forage density per linear meter of sugarcane is nearly four times greater than that of other cultures. This fact reduces the useful life of machinery and sugarcane fields as well as increases forage loss.

Even with this scenario, NUSSIO et al. (2006) showed that mechanical harvesting significantly reduced production cost of roughage. When harvesting is performed with a forage harvester, losses are between 8 and 10 t fresh matter/ha, due to the “stem base” residue left by the machine (RODRIGUES et al., 2008; 2009; SCHOGOR et al., 2009). Besides this considerable loss, the productive sector has always questioned the fate of the residue obtained. The first recommendation, based on concepts of manual harvesting, was to remove this post harvest residue using pruning shears until it is level to the ground. This practice makes it almost impossible to harvest mechanically, since it would overtax the operation with increased labor. In properties that use sugarcane for large herds, hydraulic rotary mowers have been used to lower this residue. The theory is that if the post-harvest residue remains in an area, aerial shooting will occur and production and future harvesting cycles will be compromised.

Some studies have been conducted to better understand these issues. RODRIGUES et al. (2008) observed increased production when post-harvesting residue was not removed. They attributed this effect to a possible contribution of carbohydrates in stimulating plant shooting. SCHOGOR (2008) observed that after mechanical harvesting without lowering residue, aerial tillers are emitted, but only survive up to 90 days. Also, harvesting type, being manual, mechanical or mechanical with lowering, did not alter the number of basal tillers or production.

Another study to evaluate the effect of residue height on tillering and sugarcane productivity was realized by SILVA et al. (2009). Three cutting heights were analyzed (0, 10 and 20 cm, above soil level). Heights 10 and 20 cm presented the greatest tillering, with this effect being attributed to reserve energy accumulated in the stalk base, especially under unfavorable climatic conditions. However, this increased tillering did not result in increased productivity, considering as mentioned above that lowering this residue would be another production cost. In this way, considering the inability of harvesters to work with sugarcane near the soil surface, a lack of productivity differences in the previous cut may be a good result.

3.5. Burning

The time that sugarcane is physiologically mature, in other words harvesting time, is during the dry period of the year. This is one of the features that make sugarcane interesting for use in animal feed; however, the risk of accidental or deliberate fire during this time of year is high. This scenario raises the issue of what can be done if the sugarcane field is burned.

Research considering accidental burning of sugarcane fields used for animal feed is deficient. BARBIERI & SILA (2008) claim that burning temperature and time directly influence the intensity of the process of exuding juice from the stems. This is an extremely important aspect, because with juice exudation, yeast growth before ensiling is stimulated due to increased substrate availability for microorganism growth. ROTH et al. (2010) noted this fact while performing yeast counts (Figure 1) in a sugarcane field after burning.

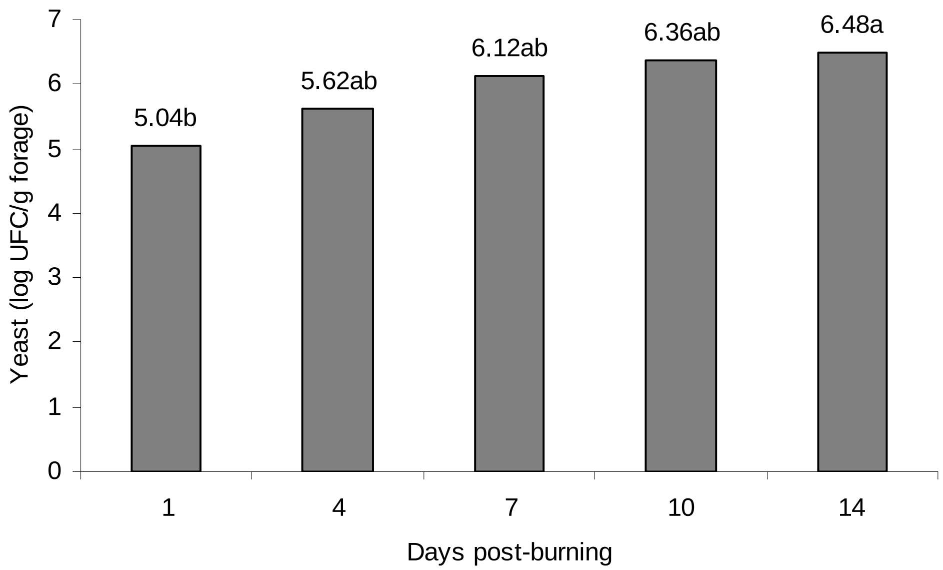

Figure 1. Yeast population count in sugarcane related to time after burning.
Source: Roth et al. (2010)

In addition to juice exudation, another consequence of sugarcane burning is altered sugar composition. ROTH (2009) noted that the Brix concentration was not changed over time after burning, but changes in the composition of total soluble solids, reducing sugar content, and reduced sucrose content over time after burning (Figure 2). The author attributes this fact to the action of invertases that are able to convert sucrose into glucose and fructose (reducing sugars). The activity of this enzyme could have been stimulated by the high temperatures that occurred during the burning of the sugarcane.

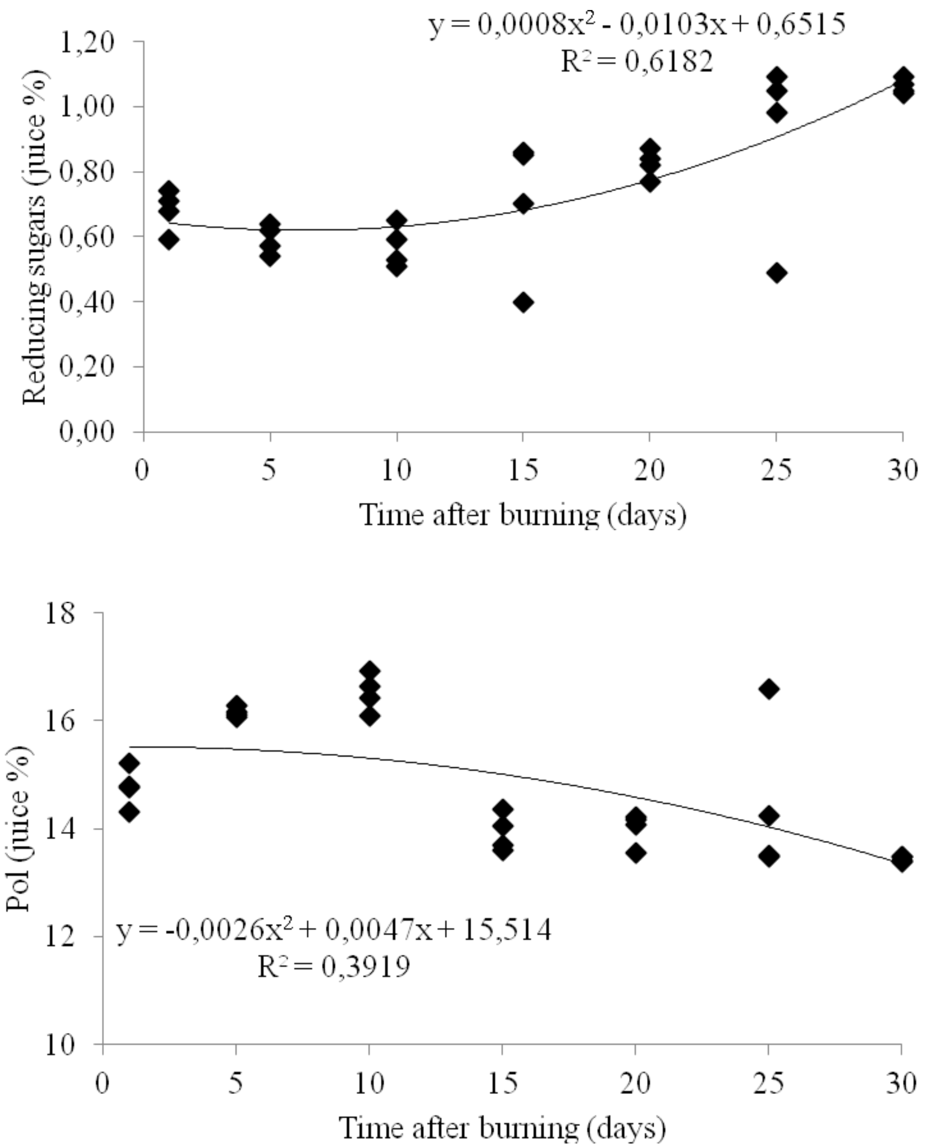

Figure 2. Juice levels of reducing sugar (fructose + glucose) (A) and sucrose (B) in sugarcane harvested after different times following burning

Adapted from Roth (2009)

The effect of high temperatures during burning were cited by BERNARDES et al. (2007) as destructive to the wax layer that surrounds the cell wall, which causes cracks in the stem and subsequent exudation of cell content (sugars), increasing chances of microbial contamination. Temperature increases and sugarcane storage for long times can cause sucrose to break down into glucose and fructose, which can facilitate alcoholic fermentation by yeast. The authors reported higher yeast counts and ethanol production in burned sugarcane compared to fresh sugarcane.

SIQUEIRA et al. (2011d) raised the following question: “My sugarcane burned. What can I do and how long do I have to take action?” After extensive review, the authors suggested ensiling sugarcane after burning, if the producer needs to use this forage resource for an extended period of time. Based on available information, the window to cut sugarcane for beef cattle feed is 10 days after burning. For dairy cows, studies confirming this hypothesis need to be performed.

4. FINAL CONSIDERATIONS

Most research on agricultural management is performed to evaluate its effect on sugarcane destined for the sugar-alcohol sector. Studies seeking to quantify its effects on silage and animal nutrition are rare.

Variety choice should be based primarily on productivity and secondly on the search for improved quality of the fibrous portion, aiming to maximize production of digestible organic matter per area.

Use of the concept of early, average and late varieties need to be adopted by producers so that forage is always used at its best nutritional value.

Reduced spacing appears to be an interesting alternative to either increase productivity or facilitate sugarcane harvesting.

After mechanical harvesting post harvesting residue stimulates tillering and does not compromise productivity of the next cycle.

5. Bibliography

AMARAL, R.C.; PIRES, A.V.; SUSIN, I. et al. Cana-de-açúcar ensilada com ou sem aditivos químicos: fermentação e composição química. **Revista Brasileira de Zootecnia**, v.38, n.8, p.1413-1421, 2009.

ANDRADE, J.B.; FERRARI Jr., E.; POSSENTI, R.A. . et al. Seleção de 39 variedades de cana-de-açúcar para alimentação animal. **Brazilian Journal of Veterinary Research and Animal Science**, v.40, n.4, p.287-296, 2003.

ÁVILA, C.L.S.; PINTO, J.C.; FIGUEIREDO, H.C.P. et al. Effects of an indigenous and a commercial Lactobacillus buchneri strain on quality of sugar cane silage. **Grass and Forage Science**, v. 64, n.1, p.384-394, 2009.

ÁVILA, C.L.S.; VALERIANO, A.R.; PINTO, J.C. et al. Chemical and microbiological characteristics of sugar cane silages treated with microbial inoculants. **Revista Brasileira de Zootecnia**, v.39, n.1, p.25-32, 2010.

BALIEIRO NETO, G.; SIQUEIRA, G.R.; REIS, R.A. et al. Óxido de cálcio como aditivo na ensilagem de cana-de-açúcar. **Revista Brasileira de Zootecnia,** v.36, n.5, p.1231-1239, 2007.

BARBIERI, V.; SILVA, F.C. da. Influência da queima nas temperaturas dos colmos da cana-de-açúcar e da superfície do solo. **HOLOS Environment,** v. 8, n. 1, p. 45, 2008.

BASILE FILHO, A. **Desenvolvimento, produção e qualidade tecnológica de três variedades de cana-de-açúcar, conduzidas sob espaçamento reduzido e tradicional de plantio em condições de cana-de-ano**. Piracicaba: Escola Superior Luiz de Queiroz, 1992. 114p. Dissertação (Mestrado em Agronomia) - Escola Superior Luiz de Queiroz, 1992.

BERNARDES, T.F.; REIS, R.A.; SIQUEIRA, G.R. et al. Avaliação da queima e da adição de milho desintegrado com palha e sabugo na ensilagem de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.36, n.2, p.269-275, 2007.

BONOMO, P.; CARDOSO, C.M.M.; PEDREIRA, M.S. et al. Potencial forrageiro de variedades de cana-de-açúcar para alimentação de ruminantes. **Acta Scientiarium. Animal Sciences**, v.31, n.1, p.53-59, 2009.

CARVALHO, M.V.; RODRIGUES, P.H.M.; LIMA, M.L.P. et al. Composição bromatológica e digestibilidade de cana-de-açúcar colhida em duas épocas do ano. **Brazilian Journal of Veterinary Research and Animal Science**, v.47, n.4, p.298-306, 2010.

CAVALI, J. **Cana-de-açúcar ensilada com óxido de cálcio, capim-elefante ou inoculante bacteriano.** 2006. 60p. Dissertação (Mestrado em Zootecnia) – Universidade Federal de Viçosa, Viçosa, 2006.

CORRÊA, C.E.S.; PEREIRA, M.N.; OLIVEIRA, S.G. et al. Performance of Holstein cows fed sugarcane or corn silages of different grain textures. **Scientia Agricola**, v.60, p.221-229, 2003.

EVANGELISTA, A.R.; SIQUEIRA, G.R.; LIMA, J.A. et al. Perfil fermentativo de silagens de cana-de-açúcar com e sem inclusão de milho desintegrado com palha e sabugo. **Revista Brasileira de Zootecnia**, v.38, n.1, p.20-26, 2009.

FERNANDES, A.M.; QUEIROZ, A.C.; PEREIRA, J.C. et al. Composição químico-bromatológica de variedades de cana-de-açúcar (*Saccharum* spp.L.) com diferentes ciclos de produção (precoce e intermediário) em três idades de colheita. **Revista Brasileira de Zootecnia**, v.32, n.4, p.977-985, 2003.

FERREIRA, D.A.; GONÇALVES, L.C.; MOLINA, L.R. et al. Características de fermentação da silagem de cana-de-açúcar tratada com uréia, zeólita, inoculante bacteriano e inoculante bacteriano/enzimático. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.59, n.2, p.423-433, 2007.

GALVANI, E.; BARBIERI, V.; PEREIRA, A.B. et al. Efeitos de diferentes espaçamentos entre sulcos na produtividade agrícola da cana-de-açúcar (Saccharum spp.). **Scientia Agricola**, v.54, n.1-2, p.62-68, 1997.

KUNG Jr, L. STANLEY, R.W. Effect of stage maturity on the nutritive value of whole plant sugarcane preserved as silage. Journal of Animal Science. V.54, n.4, p. 689-696.

LONG, S. P. 1999. Environmental responses. Pages 215-249 in C4 plant biology. R. F. Sage and R. K. Monson eds. Academic Press. New York.

LOPES, J.; EVANGELISTA, A.R. Características bromatológicas, fermentativas e população de leveduras de silagens de cana-de-açúcar acrescidas de uréia e aditivos absorventes de umidade. **Revista Brasileira de Zootecnia**, v.36, n.3, p.558-564, 2007.

MACEDO, T.M.; PIRES, A.J.V.; CARVALHO, G.G.P. et al. Degradabilidade da matéria seca e a fração fibrosa da cana de açúcar tratada com óxido de cálcio. **Revista Brasileira de Saúde e Produção Animal,** v.12, n.2, p.429-440, 2011.

MAGALHÃES, A. L. R.; CAMPOS, J. M. S.; CABRAL, L. S. et al. Cana-de-açúcar em substituição à silagem de milho em dietas para vacas em lactação: parâmetros digestivos e ruminais. **Revista Brasileira de Zootecnia**, v. 35, p. 591-599, 2006.

MALDONADO, J.G.M. **Associação de aditivos químicos e microbianos no controle da fermentação e estabilidade aeróbia em silagens de cana-de-açúcar (*Saccharum officinarum* L.)**. 2007. 99p. Dissertação (Mestrado em Agronomia: Ciência Animal e Pastagem) - Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, 2007.

McDONALD, P.; HENDERSON, A .R.; HERON, S. J. E. **The biochemistry of silage**. 2.ed. Marlow: Chalcomb Publications, 1991. 340 p.

MIGUEL, F.B.; ESPERANCINI, M.S.T.; GRIZOTTO, R.K. et al. Análise de rentabilidade e risco na produção de cana-de-açúcar na região norte do Estado de São Paulo sob dois tipos de arranjos contratuais. **Revista Energia na Agricultura**, v. 26, n.1, p.21-38, 2011.

MOSER, L. E., BURSON, B. L.; SOLLENBERGER, L. E. Warm-season (C4) grasses overview. In: **Warm-season (C4) grasses**. L.E. Moser, B.L. Burson, L.E. Sollenberger, ed. Agronomy Monographs. 45. ASA, CSSA, and SSSA. Madison, WI, 2004, p.1-14.

MURARO, G.B. ROSSI Jr., P.; SCHOGOR, A.L.B. Produção de biomassa de cana-de-açúcar em dois espaçamentos e duas frequências de corte. **Ciência e Agrotecnologia**, v. 35, n.1, p.131-136, 2011.

MURARO, G.B.; ROSSI Jr., P.; OLIVEIRA, V.C. et al. Efeito da idade de corte sobre a composição bromatológica e as características de cana-de-açúcar plantada em dois espaçamentos e três idades de corte. **Revista Brasileira de Zootecnia**, v.38, n.8, p.1525-1531, 2009.

NUSSIO, L.G.; PONCHIO, L. Cana-de-açúcar. **Revista DPA Nestlé**, maio/2004.

NUSSIO, L.G.; ROMANELLI, T.L.; ZOPOLLATTO, M. Tomada de decisão na escolha de volumosos suplementares para bovinos de corte em confinamento. In: CBNA (Ed.). **V Simpósio Goiano sobre manejo e nutrição de bovinos de corte e leite**. Campinas: CBNA, 2003. p.1-14.

NUSSIO, L.G.; SCHMIDT, P.; SCHOGOR, A.L.B.; MARI, L.J. Cana-de-açúcar como alimento para bovinos. In: PEREIRA, O.G. et al. (Eds) **Simpósio sobre manejo estratégico da pastagem, 3**. Viçosa: FUNERB, 2006. p. 277-328.

PEDROSO, A.F.; NUSSIO, L.G.; LOURES, D.R.S. et al. Efeito do tratamento com aditivos químicos e inoculantes bacterianos nas perdas e na qualidade de silagens de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.36, n.3, p.558-564, 2007.

PEDROSO, A.F.; NUSSIO, L.G.; PAZIANI, S.F. et al. Fermentation and epiphytic microflora dynamics in sugar cane silage. **Scientia Agricola**, v.62, n.5, p.427-432, 2005.

PIRES, A.J.V.; REIS, R.A.; CARVALHO, G.G.P. et al. Degradabilidade ruminal da matéria seca, da proteína bruta e da fração fibrosa de silagens de milho, de sorgo e de *Brachiaria brizantha.* **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.62, n.2, p.391-400, 2010.

RESENDE, F.D.; SIGNORETTI, R.D.; COAN, R.M. et al. Terminação de bovinos de corte com ênfase na utilização de alimentos conservados. In: REIS, R.A.; SIQUEIRA, G.R.; BERTIPAGLIA, L.M.A. (Eds). **Volumosos na produção de ruminantes**. Jaboticabal: Funep, 2005. p.83-104.

RIPOLI, T.C.C.; RIPOLI, M.L.C. **Biomassa de cana-de-açúcar:** colheita, energia e ambiente. Piracicaba: T.C.C. Ripoli, 2001. 204 p.

RODRIGUES, A.R.C.; ROMAN, J.; SIQUEIRA, G.R. et al. SCHOGOR, A.L.B.; NUSSIO, L.G.; MOURÃO, G.B.; MURARO, G.B.; SARTURI, J.O.; MATOS, B.C. Perdas das frações de cana-de-açúcar submetida a diversos métodos de colheita. **Revista Brasileira de Zootecnia**, v.38, n.8, p.1443-1450, 2009.

RODRIGUES, A.R.C.; SIQUEIRA, G.R.; BOCATTO, H.Z. et al. Correlação entre quantidade e qualidade de açúcares solúveis e perdas durante a fermentação de cana-de-açúcar. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 45, 2008, Lavras. **Anais...** Lavras: Sociedade Brasileira de Zootecnia, 2008. CD-ROM.

ROTH, A.P.T.P. **Cana-de-açúcar *in natura* e queimada ensilada com cal virgem e diferentes tempos após a queima.** 2009, 62f Dissertação (Mestrado em Zootecnia) – Faculadade de Ciências Agrárias e Veterinárias/UNESP, 2009.

ROTH, A.P.T.P.; REIS, R.A.; SIQUEIRA, G.R. et al. Sugarcane silage production treated with additives at different times post burning. **Revista Brasileira de Zootecnia**, v.39, n.1, p.88-96, 2010.

SANTOS, M.C.; NUSSIO, L.G.; MOURÃO, G.B. et al. Influência da utilização de aditivos químicos no perfil da fermentação, no valor nutritivo e nas perdas de silagens de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.37, p. 1555-1563, n.9, 2008.

SANTOS, R.V.; EVANGELISTA, A.R.; PINTO, J.C. et al. Composição química da cana-de-açúcar (*Saccharum* SPP.) e das silagens com diferentes aditivos em duas idades de corte. **Ciência e Agrotecnologia**, v.30, n.6, p.1184-1189, 2006.

SCHMIDT, P. **Perdas fermentativas na ensilagem, parâmetros digestivos e desempenho de bovinos de corte alimentados com rações contendo silagens de cana-de-açúcar.** 2006. 228p. Tese (Doutorado em Agronomia) - Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, 2006.

SCHMIDT, P.; MARI, L.J.; NUSSIO, L.G. et al. Aditivos químicos e biológicos na ensilagem de cana-de-açúcar. 1. Composição química das silagens, ingestão, digestibilidade e comportamento ingestivo. **Revista Brasileira de Zootecnia**, v.36, n.5, p.1666-1675, 2007.

SCHOGOR, A.L.B. **Avaliação agronômica da cana-de-açúcar submetida a métodos de colheita para produção animal**. 2008. 165f. Dissertação (Mestrado em Agronomia: Ciência Animal e Pastagens) – Universidade de São Paulo – Escola Superior de Agricultura "Luiz de Queiroz¨, Piracicaba, 2009.

SCHOGOR, A.L.B.; NUSSIO, L.G.; MOURÃO, G.B. et al. Perdas das frações de cana-de-açúcar submetida a diversos métodos de colheita. **Revista Brasileira de Zootecnia**, v.38, n.8, p.1443-1450, 2009.

SILVA, E.J.A.; BORGATTI, L.M.O.; MEYER, P.M. et al. Efeitos do teor de carboidratos solúveis sobre as características da silagem de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.37, n.8, p.1375-1382, 2008.

SILVA, M.A.; JERONIMO, E.M.; LÚCIO, A;D. Perfilhamento e produtividade de cana-de-açúcar com diferentes alturas de corte e épocas de colheita. **Pesquisa Agropecuária Brasileira**, v.43, n.8, p.979-986, 2008.

SILVEIRA, R.N.; BERCHIELLI, T.T.; CANESIN, R.C. et al. Influência do nitrogênio degradável no rúmen sobre a degradabilidade *in situ*, os parâmetros ruminais e a eficiência de síntese microbiana em novilhos alimentados com cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.38, n.3, p.570-579, 2009.

SIQUEIRA, G.R.; REIS, R.A.; SCHOCKEN-ITURRINO, R.P. et al. Associação entre aditivos químicos e bacterianos na ensilagem de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.36, n.4, p.789-798, 2007b.

SIQUEIRA, G.R.; REIS, R.A.; SCHOCKEN-ITURRINO, R.P. et al. Óxido de cálcio e *Lactobacillus buchneri* NCIMB 40788 na ensilagem de cana-de-açúcar *in natura* ou queimada. **Revista Brasileira de Zootecnia**, v.40, 2011b (no prelo).

SIQUEIRA, G.R.; REIS, R.A.; SCHOCKEN-ITURRINO, R.P. et al. Perdas de silagens de cana-de-açúcar tratadas com aditivos químicos e bacterianos. **Revista Brasileira de Zootecnia**, v.36, n.6, p.2000-2009, 2007a (suplemento).

SIQUEIRA, G.R.; REIS, R.A.; SCHOCKEN-ITURRINO, R.P. et al. Perfil fermentativo de silagens de cana-de-açúcar *in natura* ou queimada tratadas ou não com *L. buchneri*. **Revista Brasileira de Zootecnia**, v.40, 2011a (no prelo).

SIQUEIRA, G.R.; RESENDE, F.D.; ROMAN, J. et al. Uso estratégico de forragens conservadas em sistemas de produção de carne. In: JOBIM, C.C.; CECATO, U.; CANTO, M.W. (Eds) **Produção e utilização de forragens conservadas**. Maringá: Masson, 2008. p.41-89.

SIQUEIRA, G.R.; ROTH, M.T.P.; MORETTI, M.H. et al. Uso da cana-de-açúcar na alimentação de ruminantes. In: XXI CONGRESSO BRASILEIRO DE ZOOTECNIA. Maceió: ABZ, 2011c. CDROM.

SIQUEIRA, G.R.; ROTH, A.P.T.P.; ROTH, M.T.P. et al. Silagem de cana-de-açúcar queimada: manejo da ensilagem e desempenho de bovinos. In: EVANGELISTA, A.R. et al. (Eds) **Forragicultura e pastagens: Temas em evidência- As forrageiras e suas relações com o solo, ambiente e o animal**. Lavras:Suprema Gráfica e Editora, 2011d. p.173-195.

SOUSA, D.P.; MATTOS, W.R.S.; NUSSIO, L.G. et al. Efeito de aditivo químico e inoculantes microbianos na fermentação e no controle da produção de álcool em silagens de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.37, p.1564-1572,n.9, 2008.

TORRES, R.A.; COSTA, J.L. Uso da cana-de-açúcar na alimentação animal. In: EVANGELISTA, A.R.; SALES, E.C.J.; SIQUEIRA, G.R. et al. (Eds) Forragicultura e Pastagens: Temas em evidência. Lavras: UFLA, 2001, p.1-14.

WALKER, G. M. **Yeast physiology and biotechnology**. London: Wiley Editorial Offices, 1998, 350p.