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## Potentials and challenges in making silages using tropical forages

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**Abstract.** The cattle breeding in Brazil is almost entirely from pasture based systems, a fact that justifies the inconsistent production of meat and milk during the different seasons of the year. This inconsistency is mainly derived from the productive seasonality of forages, and the ensiling of tropical grasses is a practice of great relevance for equating the balance between demand and forage supply. The use of grasses in the form of silage has advantages such as the extensive area availability, high productivity and greater management flexibility when compared to the traditional forages used for this purpose. However, problems related to the ensiling process, such as high moisture content at the ideal cutting time, high buffering capacity, low content of soluble carbohydrates and undesirable fermentation profile contribute to the low use of these grasses in the form of silage. However, research results have shown a good quality of these silages, when the appropriate techniques are adopted during the ensiling process. This review aims to demonstrate the main advantages and hindrances for silage of tropical forage grasses.

**Keywords:** acetic acid, propionic acid, butyric acid, dry matter, NH<sub>3</sub>-N, pH

### Introduction

Pastures are important in feeding cattle worldwide. Although difficult to say, Aguiar (2017) estimated that 99% of the milk produced in Brazil, in 2014, was produced on pasture, mainly during the rainy season. Although the number of animals confined has increased in recent years, this fraction represents around 15% of the total animals (ABIEC, 2018). It is worth mentioning that, despite being confined, these animals graze the longest of the life cycle, which makes pastures more relevant as the main food source for the herd.

Tropical grasses are characterized by high production capacity per unit area, reaching between 20 and 30 tons of dry matter (DM). ha<sup>-1</sup> (DANIEL et al., 2019). On the other hand, 80-85% of the forage production is concentrated in the rainy season. The variation in forage production during the year depends on abiotic factors such as temperature, light, water seasonality (EUCLIDES et al., 2008). At the same time, the inefficiency in the use of the produced forage makes the consequences of seasonality even more evident, since the excess of forage produced during the rainy season loses

quality because it is not harvested or consumed by animals (NUSSIO & RIBEIRO, 2008).

Thus, forage consumption is constant in most properties during the year, while forage production, in tropical conditions, extrapolates demand in the rainy season and is lacking in the dry season. Meat or milk production systems are maximized when there is a balance between food production and consumption (PAULINO et al., 2004). The main results of the instability between forage supply and demand can be seen in the asymmetric weight gain of cattle kept in pastures (accordion cattle) and in the milk production seasonality, which differ in the dry and rainy periods. Silage is considered a strategy to reduce the impact of the productive seasonality of tropical grasses and guarantee food for the herd throughout the year, although corn silage is the most common, as it has a high energy source when compared to other grasses. Sorghum, sugar cane and tropical grass are also used for silage (DANIEL et al., 2019).

For a long period, the genus *Pennisetum* was the main tropical grass used for silage, however, the highest dry matter content of plants of the genera *Megathyrsus* and *Urochloa* at the time of cutting, as

well as its greater representativeness in areas intended for livestock, has been highlighted in the last decades (NUSSIO et al., 2002). The inefficiency in the production of tropical forages, accompanied by losses during the harvesting and silage process, has resulted in less use of tropical grass silages (PEDROSO, 2008).

The production of high quality silage depends on several factors, the main ones being the dry matter content, the amount of soluble carbohydrates and the low buffering capacity (SILVA et al., 2017). Factors such as the quantitative and qualitative composition of the epiphytic microflora, soluble sugars and nitrate also have little influence (REIS & MOREIRA, 2001). Finally, the cutting particle size, adequate compaction and silo closing time can also compromise the quality of the final product.

Given the importance of this issue, this study aimed to review strategies for improving silage practices based on the use of tropical forage grasses, in order to improve the use of forage and to reduce the negative impacts of productive seasonality on systems of cattle production on pasture.

#### *Silage of tropical grasses*

Factors such as high productivity, great territorial availability and management flexibility have contributed to the increased use of tropical grasses for silage (NUSSIO & RIBEIRO, 2008). Temperate (C3) and tropical (C4) grasses have a high moisture content if harvested at the moment they have the best nutritional value (DANIEL et al., 2019). Associated with this, they have a low content of soluble carbohydrates and a reduced number of endogenous bacteria, which makes it necessary to use techniques capable of increasing the dry matter content and favoring the lactic acid bacteria (BAL) to carry out the ensiling (SANTOS & ZANINE, 2006). Errors in the strategy can make it difficult to reduce the pH of the ensiled material and, consequently, compromise the quality of the final product (SCHMIDT et al., 2014).

Although the content of soluble carbohydrates is important to guarantee fermentation, the minimum amount required to reduce the pH is dependent on the buffering capacity of the forage (TOMICH, 2012). The buffering capacity is related to the crude protein content, ammonia (N-NH<sub>3</sub>), ions like Ca, K and Na, and the combination of organic acids and their salts (JOBIM et al., 2007; SANTOS et al., 2013). The fermentation process of forages with greater buffering power consumes a greater amount of soluble carbohydrates and results in greater losses (PEDROSO, 2008).

#### *Silage process*

Silage is the practice of silage production, through the anaerobic fermentation process<sup>1</sup>

(ALLEN et al., 2011). Fresh harvested material still exhibits aerobic activity by optional and mandatory aerobic microorganisms, such as molds, yeasts and some bacteria will remain active until the total consumption of oxygen present in the silo<sup>2</sup> (SILVA et al., 2017). The rapid exclusion of oxygen present in the ensiled mass, in order to restrict cellular respiration, can be achieved with the rapid filling of the silo and the adequate compacting of the material (PEDROSO, 2008). In addition, the absence of oxygen results in ideal conditions for the development of bacteria producing lactic acid, decreasing the time required to reduce the pH of the ensiled material (TOMICH, 2012). The presence of enterobacteria, clostridia and yeasts during this phase compete for substrate with lactic acid producing bacteria. However, the reduction in pH and the high osmotic pressure inactivate these microorganisms and denature the mycotoxins that, occasionally, can be found in fresh forage, resulting in the preservation of the nutritional value of the ensiled material (SILVA et al., 2017). Reducing the pH to 3.8 to 4.2 inactivates lactic acid-producing bacteria and the ensiled material is stable with biological activity practically null, if the silo is correctly sealed (PEDROSO, 2008; SURGE et al., 2010).

Tomich et al. (2003) proposed the classification of the fermentation pattern of silages based on pH, N-NH<sub>3</sub> / NT, on the content of acetic acid and butyric acid. With regard to N-NH<sub>3</sub>, the authors suggested that silages with less than 10% N-NH<sub>3</sub> / NT showed an efficient fermentation pattern, while increasing levels are related to quality reduction. Reduced levels of acetic acid and butyric acid are also characteristic of silages with an adequate fermentation pattern. Kung Jr et al. (2018) cited that in silages with a good fermentative pattern the amount of acetic acid varies from 1 to 3% of DM, while the presence of butyric acid should not be detected in silages with good fermentation. With regard to propionic acid, it has been observed that its presence is usually undetectable in good silages, with values commonly less than 0.1% (KUNG JR. Et al., 2018).

#### *Silage moment*

Knowing the ideal silage time is essential for the success of the process. Grass silage with a moisture content greater than 70% increases the chances of poor silage, as well as losses from effluents (SCHMIDT et al., 2014). The effluent losses can be less if the compaction does not exceed the density of 550 kg of green matter / m<sup>3</sup> (TOMICH et al., 2003). Forages with a high moisture content favor butyric fermentation and the release of ammonia, which will reduce the consumption of silage by animals (SANTOS & ZANINE, 2006). On

<sup>1</sup>anaerobic fermentation process. The moisture content is generally greater than 500 g kg<sup>-1</sup> of forage.

<sup>2</sup>Silo is the area destined for the storage and preservation of ensiled material. Source: ALLEN et al., 2011.

<sup>1</sup>Silage is forage containing high moisture content, harvested and preserved through the production of organic acids by the

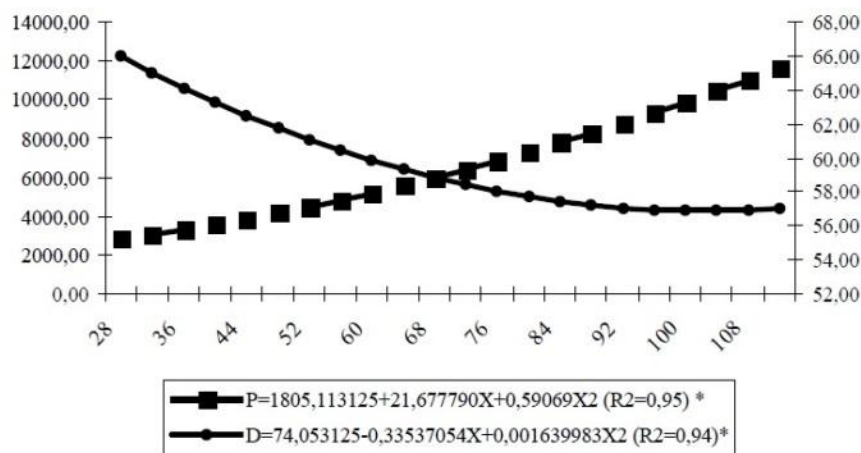
the other hand, forages with a high dry matter content make it difficult to compact the ensiled material, reducing the efficiency of air expulsion (SANTOS et al., 2013). In addition, high levels of dry matter favor fungal activity, the production of mycotoxins, the activity of enterobacteria and the increase in gas losses, releasing water, CO<sub>2</sub> and increasing the mass temperature, which may result in the Maillard reaction. In general, the ideal density for a good fermentation pattern varies from 600 to 800 kg of green matter / m<sup>3</sup> (TOMICHA et al., 2003).

Jayme et al. (2009) reported that the time of harvesting *Urochloa brizantha* cv. Marandu (marandu grass) for silage production interferes in the final quality, since the cutting ages of 28, 56, 84 and 112 days influenced the dry matter, dry matter production, N-NH<sub>3</sub> and pH levels. The lowest levels of dry matter were observed in the cut at 28 days, being similar to the forage harvested at 84 days (17.16 and 17.16%). However, the value observed in the other ages was different from each other (p <0.05), with the highest value observed in the forage with 112 days of age in relation to that of 56 days (22.62 vs. 18.83). For the production of dry matter there was an effect of the cutting ages, with an increasing increase in production with advancing age. The highest N-NH<sub>3</sub> / NT content was observed in the silage with age of cut at 28 days (14.38), with no difference being observed among the others, with the values of 3.29; 5.94 and 3.64 for the ages of 56, 84 and 112 days, respectively. As a result, the pH of the silages showed a positive correlation with the levels of N-NH<sub>3</sub> (r = 0.75; p <0.01) and a negative correlation with the content of DM (r = -0.45; p <0.03).

However, in view of the worse result of the fermentative pattern at 28 days of cutting, even with superior in vitro digestibility of dry matter in relation to other ages, the suggestion of the time of harvest should be considered by the association of dry matter production with digestibility "in vitro" of dry matter, that is, the indication was for cutting in 68 days (Figure 1).

Although the regrowth age is used as a cutting criterion for silage, since the association between age and maturity influences the quality and age of cutting or grazing forage plants (VAN SOEST, 1994), the knowledge about the primary production of plant in association with environmental factors may object to this criterion.

Pinho et al. (2013) evaluated the quality of buffel grass (*Cenchrus ciliaris*) silage submitted to four cutting heights (30, 40, 50 and 60 cm) at 10 cm from the soil. The greatest decrease in pH was observed in silage from grass harvested at 50 cm in height, although with the exception of silage from grass harvested at 30 cm in height, the other silages showed adequate pH at the end of 30 days of fermentation. Quadratic effect was observed for the lactic acid concentration, with the highest value for the silage harvested at 50 days of regrowth. The lowest concentration of acetic acid was observed in the silage harvested at 50 days of regrowth, and the concentration of butyric acid decreased linearly with the increase in the cutting height. Based on a series of factors the authors came to the conclusion that the best time for silage of buffel grass is 50 cm high.



**Figure 1** - Dry matter production curves (■) of *Urochloa brizantha* and digestibility "in vitro" of dry matter (●) of *Urochloa brizantha* silages as a function of cutting ages. \* Significant at 1% by the SNK test.

Source: JAYME et al. (2009).

**Table 1** - Average values for the concentration of ammoniacal nitrogen, lactic acid, acetic acid and butyric acid from buffel grass silage harvested at different cutting heights.

	Cutting height (cm)				CV (%)
	30	40	50	60	
N-NH3 (g/kg NT)	70.9	35.8	48.0	50.8	17.01
lactic acid (g/kg MS)	23.8	26.7	28.3	21.7	12.30
acetic acid (g/kg MS)	11.4	14.0	9.3	16.5	20.44
butyric acid (g/kg MS)	1.8	1.8	1.6	1.4	24.98

Centimeters (cm), Coefficient of variance (CV).

Source: Pinho et al. (2013).

#### Particle size

The damages caused to the vegetal tissue during the processing of the material to be ensiled modify the fermentative pattern (NUSSIO et al., 2002). Materials with high particle size make it difficult to eliminate oxygen during the compaction process, since the ensiled mass has greater porosity (REGO et al., 2015). In addition, the reduction in particle size can increase the compression and density of the ensiled mass, aiding in the expulsion of air and in the fermentation process, by improving the anaerobic environment, with a sharp drop in pH, reducing the proliferation of undesirable microorganisms and reducing butyric fermentation (SANTOS et al., 2010; SANTOS et al., 2013). Materials with high moisture content and the disruption of the plant cell wall caused by the reduction of particle size result in losses by effluents (SANTOS et al., 2010). Adopting strategies such as wilting or the use of moisture scavengers promote the absorption of free water and an increase in the carbohydrate content in the ensiled mass, reducing losses by effluents and undesirable fermentations (NUSSIO et al., 2002). The indication is that the forage is crushed with a particle size between 2-2.5 cm (TOMICH et al., 2003).

#### Withering

Field wilting (pre-drying) strategies are ideal for reducing moisture in crops of short height and thin stem (eg grasses of the genus *Urochloa*), however many species of tropical grasses used for silage are tall and have thick stems ( eg *Megathyrsus* and *Pennisetum*), which makes dehydration difficult in field conditions (DANIEL et al., 2019). Adequate silage fermentation depends on the dry matter content and the amount of soluble carbohydrates present in the forage. The adequate dry matter values are around 300-500 g / kg of MN and the amount of 60-120 g of carbohydrates / kg dry matter (SILVA et al., 2017). However, the higher the humidity of the plant, the greater the need for soluble carbohydrates (PEDROSO, 2008). Thus, one of the benefits of wilting is the increase in the concentration of fermentable substrates and the reduction of undesirable bacteria, in addition to reducing effluents (SANTOS et al., 2010). On the other hand, wilting too much consumes soluble carbohydrates and decreases the quality of the final product, in addition to increasing contamination by fungi and yeasts in the ensiled material (SANTOS et al., 2010). Although simple, this technique requires

greater initial investment, since it is necessary to acquire specific machinery (SCHMIDT et al., 2014), in addition to resulting in increased losses in field conditions (DANIEL et al., 2019).

The effect of different periods of pre-wilting of marandu grass (0, 2, 4, 6 hours) and their reflexes on dry matter, pH, buffer power and N-NH3 of the silage was evaluated by Evangelista et al. (2004). The authors observed a linear response due to the increase in wilting time on the dry matter content before silage ( $Y = 27.2213 + 5.87940 x$ ;  $R^2 0.9276$ ), silage dry matter content ( $Y = 25,8540 + 5.67612 x$ ;  $R^2 0.9452$ ), buffering power ( $Y = 21.3300 - 1.58915 x$ ;  $R^2 0.8810$ ) and silage pH ( $Y = 3.5675 + 0.0975 x$ ;  $R^2 0.7339$ ). For N-NH3, no difference was observed between wilting periods, with levels ranging from 1.96 to 2.72 of N-Total. Thus, the authors suggested that the wilting period of marandu grass aged 90 days should be between 1.32 to 3.02 hours, combining technical and operational advantages.

#### Moisture scavengers

Grass silage together with moisture-scavenging foods can produce silages with minimal effluent loss, high intake potential and improved dry matter digestibility, depending on the absorbent used (DANIEL et al., 2019).

Ribeiro et al. (2014) evaluated the addition of 0, 6, 12 and 18% castor bean cake in ensiled elephant grass and in elephant grass withered by exposure to the sun for 8 hours; found that the addition of 12 and 18% castor bean cake showed greater moisture reduction than the wilting technique. Lower levels of dry matter were observed in elephantgrass silage without the addition of castor cake, with a dry matter content of the material with an addition of 6% similar to that of withered elephantgrass (26.1 vs. 25.3 ). The highest dry matter contents were for the ensiled materials with the addition of 12 and 18% castor cake (29.0 vs. 31.9). Despite the greater efficiency with the use of moisture scavengers in tropical grass silages, the difficulty of homogenizing the material in ensiled mass, coupled with acquisition problems and the high cost of the concentrate observed in some regions of the country may prevent the adoption of this technique (DANIEL et al., 2019).

#### Microbial additives

Microbial inoculants can replace moisture scavengers in the ensiling process of tropical grasses (SCHMIDT et al., 2014). These additives

increase the population of microorganisms and favor the fermentation of ensiled material, consequently reducing dry matter losses (TOMICH, 2012). Some additives, such as *Lactobacillus buchneri*, can inhibit the growth of fungi and yeasts, ensuring greater aerobic stability of the ensiled product (NUSSIO & RIBEIRO, 2008).

Bacterial inoculants can be divided into two types. The first, formed by homofermentative bacteria (also called facultative heterofermentatives) has the ability to maximize the production of lactic acid and accelerate the pH drop of silages. The second type, formed by mandatory heterofermentative bacteria, produces lactic, acetic and propionic acid with the ability to increase the aerobic stability of silages when exposed to air (SCHMIDT et al., 2014). However, it is important to note that there are mandatory homofermentative bacteria, that is, not all homofermentative bacteria are facultative heterofermentatives and vice versa.

Muck et al. (2018) reported that silage additives decrease silage management problems, including the rapid production of lactic acid and decrease in pH, in order to avoid clostridic fermentation, as well as reduce the yeast population, making the silage aerobically stable and improving animal performance.

The use of lactic acid-producing microorganisms has been reported for over 100 years, being first used to improve the fermentation of beet residues (SCHMIDT et al., 2014). Since then, methods have been developed to select beneficial bacteria for the production of lactic acid. Ávila et al. (2009) reported that until a few years ago, most microbial inoculants contained only homofermentative lactic bacteria, more efficient in reducing pH and restricting protein degradation, in addition to reducing dry matter losses during the fermentation process, however from problems related to aerobic deterioration, it became necessary to search for inoculants capable of circumventing this problem.

In grass silages it is common to use compounds of homofermentative bacteria. Although in corn and sorghum silages the use of homofermentative bacteria is a negative point, since aerobic stability is reduced, in grass silages this phenomenon does not occur due to the low availability of substrate.

Cezário et al (2015) evaluated the marandu grass silage harvested with 35 and 70 days of regrowth and submitted or not to inoculation with microbial additives. The results did not demonstrate the effect of the age of growth and the use of the inoculant in the chemical composition, losses by gases and effluents, in the recovery of dry matter, pH and N-NH<sub>3</sub> of the evaluated silages. Marandu grass silages harvested at 35 days of growth, regardless of the use or not of microbial inoculation, showed more lactic acid than in plant silage harvested at 70 days. When harvested at 35 days of regrowth, propionic acid was higher in the inoculated silage. Among the uninoculated silages, the highest propionic acid content was found in the silage harvested at 70 days ( $p < 0.01$ ). No differences were observed in relation to butyric acid for the inoculated or not inoculated silages, but the highest content of butyric acid was observed in the silage harvested at 35 days of regrowth and not submitted to inoculation ( $p < 0.01$ ).

These results showed that the use of bacterial inoculants may not be successful. For Nussio and Ribeiro (2008), this fact can be justified by some factors, such as: existence of a sufficient population of epiphytic or endophytic microorganisms, use of inappropriate microorganisms and inadequate amount of fermentable substrates, resulting in the inability of these microorganisms to act. For Muck (1988) this problem may be related to the ability of the inoculated bacteria to grow in the ensiled mass, as well as to have some specificity between the forage species and the microorganisms present in the inoculant. Under this hypothesis, Hill (1989) isolated strains of *L. plantarum* from the cultures of corn, alfalfa and sorghum. The strains of the three cultures were homogenized and applied during ensiling in the respective species. The author detected that the strain originally isolated from a specific forage was dominant in the respective silage, which indicates that the bacterial strain grows better in the forage species in which it was found. This fact makes evident the existence of a specific composition of nutrients capable of guaranteeing the development of population microorganisms inherent to certain species.

**Table 2.** Fermentation parameter of *Uruchloa brizantha* cv. Marandu ensiled at 35 and 70 days of regrowth with and without inoculant and analyzed 60 days after ensiling.

Parâmetro	Control		Inoculant		EPM	P-value		
	35 d	70 d	35 d	70 d		Age	inoculant	Age*inoculant
lactic acid (g/kg MS)	45.4	18.5	24.1	18.8	1.8	<0.01	<0.01	<0.01
acetic acid (g/kg MS)	7.7	13.4	10.9	11.4	0.7	<0.01	0.39	<0.01
butyric acid (g/kg MS)	2.1	1.2	1.4	1.4	0.2	0.03	0.40	0.04

Source: Adapted from Cezário et al. (2015).

The existence of variation in the composition of epiphytic microorganisms is also very common in

forage plants and is due to several factors, such as time of year, place and age of sprouting, which may

compromise the fermentation process, requiring the use of microbial inoculants. (Ávila et al., 2014; Pereira & De Paula, 2016).

Santos et al. (2014) evaluated some characteristics of silage of mombaça grass (*Megathyrus maximus* Jacq. Mombaça) ensiled with regrowth intervals of 35, 45, 55 and 65 days, submitted or not to the use of bacterial inoculant. The microbiological composition of the plants varied according to the regrowth intervals, with the population of lactic acid bacteria ranging from 4.35 to 5.55 log cfu / g, from the smallest to the largest regrowth interval. The isolation of these bacteria showed that they were all *Lactobacillus plantarum* and showed 99% similarity. Regarding the characteristics of the ensiled material, the use of the inoculant reduced the pH in all growth intervals, with a similar effect being observed for N-NH<sub>3</sub>, except in the interval of 65 days. While the levels of lactic acid increased linearly with the growth interval, the levels

of acetic and butyric acid also decreased linearly. These data can be seen in the table below (Table 3).

The authors associated the low pH of the silage with a greater interval between regrowths with the highest content of lactic acid and the presence of bacterial inoculation. In addition, the lowest pH and the lowest N-NH<sub>3</sub> content in plants harvested in the largest regrowth periods indicated a better fermentative pattern in relation to young plants. Thus, they concluded that the population of these bacteria observed in grass ensiled with 55 and 65 days of regrowth was able to improve fermentation in relation to younger ages. Although grasses in older age have a higher population of this bacteris, the greater lignification of tissues compromises the nutritional value of these plants, a fact that makes it necessary to know when the dry matter content and the population of these bacteria are suitable for the fermentation process, in the however without compromising the nutritional value of the plant (SANTOS et al., 2013).

**Table 3.** Average values of pH, N-NH<sub>3</sub>, lactic, acetic and butyric acid in mombaça grass silages as a function of regrowth interval (IR), inoculant (I), and IR x I interaction.

Inoculante	Regrowth interval				P-value			SE
	35	45	55	65	IC	I	IR x I	
pH					<0.0001	0.037	0.45	0.05
without	5.15a	5.09a	4.84a	4.63a				
with	5.04b	4.96b	4.83b	4.44b				
N-NH <sub>3</sub> (% of N total)					<0.0001	0.042	0.18	0.26
without	9.59a	8.91a	8.22a	6.17a				
with	8.78b	8.38b	7.83b	6.09a				
Lactic acid (% MS)					<0.0001	0.0038	0.80	0.29
without	2.54b	3.15b	3.49b	4.27 <sup>a</sup>				
with	3.04a	3.61a	4.45a	4.56a				
Acetic acid (% MS)					<0.0001	0.0002	0.088	0.13
without	1.34a	1.16a	0.92a	0.89a				
with	1.15b	0.77b	0.68b	0.68b				
Butyric acid (% MS)					<0.0001	0.0049	0.043	0.04
without	0.070a	0.050a	0.040a	0.043a				
with	0.050b	0.043b	0.040a	0.040a				

a, b Means without the same superscript letter in the column differ according to the Tukey test (p <0.05). Standard error (SE).

Source: Adapted from Santos et al. (2014).

### Final considerations

The ensiling of tropical grasses is feasible due to the high forage productivity in the rainy season, however, the quality of the ensiled material will determine the final silage pattern. From a fermentative point of view, the quality of the fermentative pattern depends on aspects related to the plant, such as dry matter content, amount of soluble carbohydrates and buffering power of the culture, as well as the strategies that can be adopted to increase the quality of the final product. The use of additives as fermentative enhancers is still controversial, and in most cases it can be compromised by other factors. To obtain high quality tropical grass silages it is essential to use appropriate strategies.

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