Foreword

The Brazilian Forage Team (NEFOR) is celebrating 20th Anniversary with a special conference. With more than 10 successful events in its history, the NEFOR organizes the second CONFOR (International Conference on Forages) with practical topics discussed by renowned Brazilian and foreign researchers. Livestock systems are so much more than a farmer simply planting a seed and rearing a cow. It takes a whole ecosystem and a host of actors to work together to produce the food we need for a population of more than seven billion people. Farming in this complex and constantly changing environment raises a host of questions and problems as each day and each season bring new challenges. As a result, farmers and ranchers are always exploring new ideas and ways of doing things better. In response to a problem or some new bit of information, you experiment with new techniques, tweak your production system, observe the results and draw a conclusion: The research takes your role as a farmer/rancher to a whole new level. Based on that, our conference innovates again by performing not one, but three simultaneous events, including a field day. This Proceedings volume contains 12 invited papers divided into 3 sections and volunteered papers which will be presented as poster and oral session. Thank you very much for your contribution in making the CONFOR 2018 a successful scientific and practical event.

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Introduction

Losses from silage

Ensiling is a forage preservation process, during which lactic acid bacteria ferment water-soluble carbohydrates (WSC) to mainly lactic acid. The acid maintains a low pH that inhibits the growth of undesirable microorganisms, and the breakdown of protein and other nutrients by microbes like clostridia (Pitt and Leibensperger, 1987).

During and after ensiling, losses of DM, nutrients and energy can occur due to mechanical damage during harvesting, plant and microbial respiration, deamination and proteolysis, seepage, aerobic spoilage and feedout processes (Grant and Adesogan, 2018). In one of the earlier studies on the subject, Watson and Nash (1960; cited by McDonald, 1991) conducted a survey of 800 experiments and reported an average DM loss of 16% during ensiling. Later, Bastiman and Altman (1985) reported mean DM losses of 25% and 32% for unwilted and wilted silage, respectively after summarizing 205 ensiling experiments. Average DM losses during silage production of 14 to 24% were reported in a more recent survey by Rotz and Muck (1994), though losses exceeding 30% may occur in poorly managed silages, and they can be up to 49% if yeast dominate the microbial population (McDonalds et al., 1960; Table 1).
### Table 1 - Silage fermentation pathways and the relevant DM and energy losses (adapted from McDonald et al., 1991).

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Pathway</th>
<th>DM loss, %</th>
<th>Energy loss, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Homofermentative LAB</strong></td>
<td>Glucose/fructose $\rightarrow$ 2 lactate + $2\text{H}_2\text{O}$</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Glucose $\rightarrow$ lactate + ethanol + $\text{CO}_2$ + $\text{H}_2$</td>
<td>24.0</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>3 Fructose $\rightarrow$ lactate + acetate + 2 mannitol + $\text{CO}_2$ + $\text{H}_2$</td>
<td>4.8</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>* 2 Citrate $\rightarrow$ lactate + 3 acetate + 3 $\text{CO}_2$</td>
<td>29.7</td>
<td>+1.5</td>
</tr>
<tr>
<td></td>
<td>* Malate $\rightarrow$ lactate + $\text{CO}_2$</td>
<td>32.8</td>
<td>+1.8</td>
</tr>
<tr>
<td></td>
<td>2 Lactate $\rightarrow$ butyrate + 2 $\text{CO}_2$ + $2\text{H}_2$ + $\text{H}_2$</td>
<td>51.1</td>
<td>18.4</td>
</tr>
<tr>
<td></td>
<td>Yeasts Glucose $\rightarrow$ 2 ethanol + 2 $\text{CO}_2$ + $2\text{H}_2$ + $\text{H}_2$</td>
<td>48.9</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Enterobacteria Glucose $\rightarrow$ acetate + ethanol + 2 $\text{CO}_2$ + 2 $\text{H}_2$ + $2\text{H}_2$ + $\text{H}_2$</td>
<td>41.1</td>
<td>16.6</td>
</tr>
<tr>
<td><strong>Heterofermentative LAB</strong></td>
<td>Clostridia 2 Lactate $\rightarrow$ butyrate + 2 $\text{CO}_2$ + $2\text{H}_2$ + $\text{H}_2$</td>
<td>51.1</td>
<td>18.4</td>
</tr>
<tr>
<td></td>
<td>Yeasts Glucose $\rightarrow$ 2 ethanol + 2 $\text{CO}_2$ + $2\text{H}_2$ + $\text{H}_2$</td>
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<td>41.1</td>
<td>16.6</td>
</tr>
</tbody>
</table>

*Same pathways for homofermentative lactic acid bacteria (LAB)*
Based on a 20% DM loss estimate, a $50/ton price, and production of 128.4 million tons of whole-plant corn silage in 2017 (USDA-NASS, 2017), Grant and Adesogan (2018) reported that the economic impact of corn silage DM losses alone in the US is about $1.284 billion/yr. For all stored forages, the estimate exceeds $2 billion/yr (Rotz and Muck, 1994), and this hidden cost represents a loss of potentially useful nutrients that are vital for optimizing the profitability of dairy farms. In Brazil, about 120 million tons of whole-plant corn silage is produced yearly according to a survey conducted by Bernardes (2018, unpublished data). Assuming the same DM loss percentage (20%) and a cost of R$120/ton, the economic loss derived from DM loss of corn silage in Brazil is about R$2.8 billion/yr. For sugarcane silage, based on an estimated production of 1.5 million tons a year (Nussio, 2018, unpublished data) and similar DM loss and a cost of $85/ton, the economic losses are about R$25.5 million. These substantial financial implications are often ignored or underestimated (Adesogan, 2014).

McDonald et al. (1991) estimated total energy loss during and after ensiling to range from 7 to > 40 % depending upon the crop type and management. The energy loss from microbial fermentation was estimated to be 2 - 4 %, which is attributable to fermentation and activity of homofermentative and heterofermentative lactic acid bacteria, clostridia, enterobacteria and yeasts. In addition to that from microbial fermentation, energy losses from residual plant respiration, effluent production and aerobic deterioration during and or after ensiling range from 1 to 2%, 5 to >7% and 0 to >25%, respectively (McDonald et al., 1991). The relevant biochemical pathways and losses are listed in Table 1, which clearly shows why homofermentative pathways produce less losses than heterofermentative pathways.

Silage inoculants

Silage inoculants are freeze-dried lactic acid bacteria that are added to the forage at ensiling to facilitate the fermentation process and or improve shelf life after silo opening. The major types are homofermentative and heterofermentative bacteria. The commonly used traditional homofermentative inoculants include bacteria like Lactobacillus plantarum, L. acidophilus, Enterococcus faecium, Pediococcus acidilactici, and P. pentacaceus (Kung, 2001). However, these are now taxonomically known as facultative heterofermentative bacteria (hereafter called homofermentative bacteria or inoculants). Homofermentative inoculants ferment WSC to mainly lactic acid, which leads to a rapid decline in silage pH, lower DM losses and less proteolysis. However, such inoculants do not
consistently reduce aerobic spoilage and in fact by providing a substrate for lactate-assimilating yeasts, some increase aerobic spoilage. In a meta-analysis on effects of such inoculants, Oliveira et al. (2017) reported that inoculation with homofermentative LAB ($\geq 10^5$ cfu/g as fed) markedly increased silage fermentation and dry matter recovery in temperate and tropical grasses, alfalfa, and other legumes. However, inoculation did not improve the fermentation of corn, sorghum, or sugarcane silages or the aerobic stability of silages.

Obligate heterofermentative (hereafter called heterofermentative) bacterial inoculants are mainly used to increase the shelf life of silages. The most widely used bacteria in such inoculants is \textit{L. buchneri}, which can ferment WSC to lactic acid, acetic acid and 1, 2 propanediol, which may be converted to propionic acid, when an \textit{L. diolivorans} subpopulation is present (Krooneman et al., 2002). Acetic and propionic acids are antifungal compounds and hence, \textit{L. buchneri} application typically improves the aerobic stability of silage. Recent studies have also shown that application of \textit{L. hilgardii} is a promising strategy for increasing the aerobic stability of silage (Carvalho et al., 2014, 2015). Heterofermentative bacteria application may result in slightly higher DM losses than homofermentative bacteria but the improvement in aerobic stability of silage inoculated with the former typically compensates for such losses. Though propionibacteria strains that produce propionic acid, which is a stronger antifungal agent than acetic acid, can theoretically improve aerobic stability, their efficacy has been limited in practice, as they are often outcompeted under acidic conditions (pH $< 4.5$).

To exploit the potential of homofermentative bacteria to reduce DM losses and that of heterofermentative bacteria to increase aerobic stability, while reducing fermentation DM losses from the latter, various combinations of both types of bacteria are included in inoculants such as mixtures of \textit{L. plantarum} and \textit{P. pentosaceaus} and \textit{L. buchneri}. To illustrate the benefits of such dual-purpose inoculants, Driehuis et al. (2001) inoculated grass silage with \textit{L. buchneri} with or without \textit{L. plantarum} and reported that the mixture of \textit{L. buchneri} and \textit{L. plantarum} enhanced the fermentation process and aerobic stability and reduced DM loss. However, inoculating with \textit{L. buchneri} alone increased aerobic stability but did not reduce DM loss relative to the control.
How Inoculants Reduce Losses During Ensiling?

Inoculants contribute to reduced DM loss through their effects on fermentation quality and aerobic stability of silage. This section describes some of the underlying ways in which DM loss is reduced.

**Modes of action**

**Increased acidification**

Success of ensiling requires fast inhibition of plant respiration, proteolysis, and growth and activity of clostridia and other aerobic microorganisms, which can be achieved by rapidly reducing the pH in forages that have less than 55% DM (Muck, 1988). The effects of homofermentative or heterofermentative lactic acid bacterial inoculants on pH in silage have been reported widely (Filya et al., 2000, 2007; Arriola et al., 2011). In a study by Filya et al. (2000), ensiling fresh or wilted whole crop wheat with *L. pentosus* and a mixture of *L. plantarum* and *E. faecium* reduced pH by enhancing lactic acid production. Similarly, Arriola et al. (2011) reported that ensiling corn forage with *L. buchneri* or a combination of *L. buchneri* and *P. pentosaceaus* decreased the pH and increased lactic acid concentration compared to the uninoculated corn silages. Filya et al. (2007) reported that inoculation of first-cut alfalfa with 13 of 14 inoculants (included strains of *L. buchneri, L. plantarum, L. pentosaceus, Enterococcus faecium, Pediococcus cerevisiae, Propionibacterium jensenii, P. pentosaceus*) reduced the pH and 12 of them shifted the fermentation towards lactic acid after 30 d of ensiling.

The low pH attained inhibits the growth of epiphytic microorganisms that contribute to DM losses by producing CO$_2$ during or after hexose fermentation because they are inhibited by pH values below 4.5. Examples of such organisms include clostridia, heterofermentative bacteria, yeasts, and molds. In addition to the inhibitory effect of the low pH, the pKa (acid dissociation constant) may also be implicated because at low pH, organic acids like lactic acid are mostly in protonated states, and the protons can diffuse into bacterial cells, and cause cell death (Bjornsdottir et al., 2006).

**Reduced proteolysis and deamination**

Numerous studies have investigated the effects of inoculants on proteolysis and deamination in different forage species, most of which have been legumes because of their high protein content (Lee et al., 2008; Filya, 2003). Inoculation
How Silage Inoculants Can Reduce Losses and Increase Milk Production

of forage often inhibits proteolysis due to faster acidification, which suppresses the activity of proteolytic organisms like clostridia and enterobacteria that require a pH of above 4.6 to thrive, or which suppresses proteases, since they do not tolerate low pH. For example, pH values of 5.5, 6 and 5-7 are the optimal pH for proteases of alfalfa, red clover and ryegrass, respectively (Heron et al., 1989; Jones et al. 1995). Davies et al. (1998) reported that forages supplemented with WSC and ensiled with a lactic acid bacterial inoculant had lower NH₃-N concentration and a higher proportion of residual ribulose-1,5-bisphosphate carboxylase, a major protein of the leaf. Similarly, Filya (2003) reported that concentrations of NH₃-N in low dry matter (DM) sorghum and corn ensiled with L. plantarum or a mixture of L. plantarum and L. buchneri were reduced after 90 days of ensiling compared values in the untreated silages. The effect of inoculants on proteolysis also depends on factors like inoculant type and application rate. In the meta-analysis by Oliveira et al. (2017), NH₃-N concentration was reduced to the greatest extent when E. faecium was applied during ensiling, followed by combinations of inoculants or L. plantarum, whereas ensiling with P. pentosaceus had no effect.

**Modulated acetic acid concentration**

Unlike heterofermentative inoculants, homofermentative inoculants shift the fermentation towards lactate at the expense of volatile fatty acids like acetic and butyric acid, and alcohols like ethanol, etc., which have CO₂ as a fermentation co-product. This shift to the homofermentative pathway improves fermentation quality and often reduces DM losses. Several studies have reported that acetic acid concentration in various silages was reduced by ensiling with L. plantarum, whereas lactic acid concentration was increased (Contreras-Govea et al., 2013: Daniel et al., 2018). Contreras-Govea et al. (2013) applied L. plantarum to three alfalfa forages and one corn forage and reported that inoculation increased lactic acid and reduced acetic acid concentration but did not affect DM content of the forages. Daniel et al. (2018) reported that inoculating corn silage with a mixture of Lactococcus lactis, Lactobacillus plantarum, and Enterococcus faecium for 100 d increased lactic acid and decreased acetic acid concentration. The meta-analysis of Oliveira et al. (2017) showed that applying homofermentative or facultative heterofermentative bacterial inoculants reduced acetic acid concentration in a variety of forages such as corn, sorghum, temperate and tropical grasses, and sugarcane but not legumes. They also reported reduced acetic acid concentration in silages treated
with *L. plantarum* and combinations of inoculants but not those treated with *E. faecium* or *P. pentosaceus*, indicating the species specificity of the response.

In contrast, applying heterofermentative inoculants like *L. buchneri* increase acetic acid concentration in silage in order to exploit the antifungal properties of the acid, which result in increased aerobic stability. The DM losses that occur during the heterofermentative pathway in *L. buchneri*–treated silage are typically much less than those occur in deteriorating silage. Filya *et al.* (2007) reported that in first-cut alfalfa, ensiling with *L. pentosus*, *L. buchneri*, *E. faecium*, or *L. plantarum* or a combination of *L. buchneri* and *L. plantarum* for 30 days led to higher acetic acid concentration relative to uninoculated silages. Similarly, Hu *et al.* (2009) reported that ensiling corn silage with *L. buchneri* with or without *L. plantarum* for 240 d increased acetic acid concentration and improved aerobic stability. Nishino *et al.* (2004) also reported that inoculating with *L. buchneri* increased acetic acid concentration, aerobic stability and decreased lactic acid concentration in whole crop silage.

**Inhibition of spoilage organisms and their fermentation products**

Silage spoilage can be indicated by high pH, excessive production of CO₂ and growth of yeasts and molds (Filya and Sucu, 2007). The high ethanol level and CO₂ production are products of fermentation of sugars and lactic acid by yeasts (Woolford, 1990). A number of studies have reported improvement in aerobic stability and reductions in DM losses in a variety of silages treated with inoculants. Ranjit and Kung (2000) ensiled corn forage with *L. buchneri* at 10⁶ cfu/g for 100 d and reported that the inoculant reduced yeast counts and drastically improved the aerobic stability to greater than 900 h compared to the uninoculated corn silage, which was only stable for 26 h. Interestingly, inoculating with *L. buchneri* at 10⁵ cfu/g only kept the silage stable for 37 h, emphasizing the importance of the correct inoculant dose. Filya (2003) reported reduced CO₂ production and yeast and mold counts in corn and sorghum silage ensiled with *L. buchneri* for 90 d. Similarly, Filya and Sucu (2007) reported that ensiling wheat, sorghum and corn silages with *L. buchneri* or *Propionibacterium acidipropionici* reduced yeast counts and decreased CO₂ production. Reich and Kung (2010) also reported that ensiling corn silage with *L. buchneri* mixed with *L. plantarum* and *P. acidilactici* for 215 days increased acetic acid concentration, aerobic stability and DM recovery. In addition, Arriola *et al.* (2011) ensiled corn silage with *L. buchneri* for 575 d and observed a decrease of DM loss from 14.3 to 5% compared to the control. In our previous farm scale study, inoculation with a mixture of *Pediococcus pentosaceus* and *L. buchneri* decreased yeast
counts and the percentage of spoiled silage by over 50% from 7.8 to 3.4%, and consequently reduced the losses of CP, NDF, ADF and gross energy by 70, 67, 68, and 66%, respectively (Queiroz et al. 2012). Furthermore, our most recent meta-analysis of 103 studies showed that inoculation with heterofermentative bacteria increased DM recovery and aerobic stability (Oliveira et al., 2018, unpublished data).

Collectively, increased acidification, reduced proteolysis and deamination, acetate modulation and inhibition of the spoilage organisms contribute to reduced DM losses but the individual contributions of each of these components are unknown.

### How Inoculants Increase Milk Production

**Inoculant effects on animal performance**

Although the primary aims of inoculant application are to increase acidification or reduce spoilage, several studies have shown the desirable additional outcome of improved animal performance. However, the response has been equivocal. The milk yield response to feeding inoculated silages has varied from none (Kristensen et al., 2010; Arriola et al., 2011), to trends for higher milk yield (Bayatkouhsar et al., 2011; Ellis et al., 2016) to significantly higher milk yield (Gordon, 1989, Kung et al., 1993). The variation in the response is attributable to various factors like the bacterial species, strain, viability, dose and composition, ensiling duration, type and chop length of the forage, inclusion rate of silage in the diet, feedout rate and lactation stage of cows. Weinberg and Muck (1996) summarized studies that tested the effects of inoculant-treated silage on the performance of dairy cows and reported that 6 out of 8 studies reported increased milk yield. In our recent meta-analysis (Oliveira et al., 2017) of 38 dairy cow feeding studies, milk yield was increased by 0.37 kg/d when silages were inoculated with homofermentative lactic acid bacteria. Researchers have long sought to understand how silage inoculants increase animal performance and the ensuing section summarizes some of the underlying strategies.

**Modes of action**

The modes of action associated with increased performance include increased intake, increased digestibility of DM and NDF, improved rumen
function or fermentation, increased microbial growth, probiotic effects and inhibition of spoilage and pathogenic organisms.

**Increased intake**

Since intake is one of the main drivers of milk production, any factor that increases intake may increase milk production. Gordon (1989) fed herbage ensiled with or without *L. plantarum* to dairy cows for 88 d and reported greater (2.1 kg/d) milk yield in cows fed the inoculated silage. This was attributed to higher metabolizable energy intake (12%) from the inoculated silage, which is highly correlated to energy-corrected milk production (ECM, $R^2 = 0.74$; Huhtanen *et al.*, 2002). Mayne (1990) reported that feeding *L. plantarum*-inoculated ryegrass silage to dairy cows increased silage intake by 14%, and as a result of the higher energy intake, milk yield was increased by 1.1 kg/d. In a study by Winters *et al.* (2001), feeding *L. plantarum*-inoculated ryegrass silage to beef steers increased DM intake from 7.4 to 8.2 kg/d and liveweight gain by 42% compared to the control. Higher intake of DM and energy with greater average daily gain and feed efficiency, were also reported in beef bulls fed chopped sugarcane ensiled with *L. buchneri* versus the control silage (Schmidt *et al.*, 2014). Furthermore, inoculating corn forage with *L. plantarum* increased DM intake and 3.5% fat-corrected milk production by dairy cows (Kung *et al.*, 1993), and inoculating mixture of *L. buchneri* and *L. plantarum* increased DMI and average daily gain in lambs (Basso *et al.*, 2014).

**Increased digestibility**

Inoculants have also increased silage digestibility *in vitro* and *in vivo*. Weinberg *et al.* (2007) reported increased in vitro digestibility of DM and neutral detergent fiber (NDF) after ensiling whole-plant wheat or corn silage with different strains of *Enterococcus faecium* or *L. buchneri* or a combination of *L. plantarum* and *E. faecium*. In another study by Nsereko *et al.*, (2008), inoculating corn silage with various strains of *L. brevis*, *L. buchneri*, *L. reuteri* and *L. crispatus* that produce ferulate esterase increased the in situ digestibility of NDF by 9 to 11%. Similarly, McAllister *et al.* (1998) reported increased total tract digestibility of DM and organic matter in lambs fed alfalfa silage inoculated with *L. plantarum*. Daniel *et al.* (2018) also reported that inoculating corn silage with a mixture of *Lactococcus lactis*, *Lactobacillus plantarum*, and *Enterococcus faecium* increased DM digestibility and consequently increased fat-corrected milk production by dairy cows. The increase in digestibility was attributed to the hydrolytic effect of enzymes produced by the bacteria. Cell
How Silage Inoculants Can Reduce Losses and Increase Milk Production

Wall hydrolysis by the acidity resulting from improved fermentation or added enzymes may be implicated in other cases. Inoculation with homofermentative bacteria may also enhance digestibility indirectly by increasing lactic acid supply. Diet supplementation with lactic acid has been associated with higher rumen pH (Jaakkola and Huhtanen, 1989; Daniel et al., 2013), which may contribute to the higher diet digestibility by improving conditions for cellulolytic bacteria.

**Increased rumen function**

Inoculants may increase animal performance by improving rumen fermentation. In a study by Mohammed et al. (2012), inoculating alfalfa with *L. plantarum* at $10^5$ cfu/g reduced the pH by increasing lactic acid concentration. Cows fed the inoculated silage had higher ruminal total VFA concentration, which probably increased supply of nutrients for milk production. However, perhaps due to the small number (8) of animals used in their study, the increased in milk production was just numerical (inoculated vs. control, 37.7 vs. 36.9 kg/d). In another study by Addah et al. (2015), inoculation of whole-crop barley with an *L. buchneri* strain that produces ferulic acid esterase, reduced the duration of time under which ruminal pH was below 5.8, 5.5 and 5.2 in steers, and increased the mean ruminal pH from 5.79 to 5.91. Therefore, certain inoculants may improve rumen function by reducing ruminal acidosis. Interestingly, such effects were only observed in silages that were chopped to 2 cm but not those chopped to 1 cm, suggesting that the benefits of inoculation applied when the particle size was greater.

**Increased microbial growth**

Basso et al. (2014) showed that when corn forage was inoculated with *L. buchneri* and fed to lambs, nitrogen retention was increased due to a notable increase in microbial protein yield in the inoculated silage diet. Contreras-Govea et al. (2011) inoculated whole crop alfalfa, brown mid-rib corn and normal corn forage for 60 d and examined the effects of inoculants on ruminal fermentation and microbial biomass in vitro. They reported that 3 of the 4 inoculants tested, *L. plantarum, L. pentosus,* and *L. lactis,* improved microbial biomass yield from 35 to 38-39 mg/100mg of digestible DM compared to the control. They suggested that better preservation of protein during ensiling might have played a role in improving the microbial biomass yield. Similarly, in another study by the same group (Contreras-Govea et al., 2013), alfalfa and corn silage ensiled with *L. plantarum* for 60 d had higher microbial biomass yield and higher
microbial non-ammonia N than control silages. Such increases in microbial biomass may lead to an increase in milk protein yield because over 70% of milk protein originates from microbial protein (NRC, 2001) and milk protein is correlated positively with the intestinal microbial protein supply ($R^2 = 0.98$; Huhtanen et al., 2008).

**Probiotic effect**

Probiotics are microorganisms that can increase ruminal function or animal performance and or health. Inoculant lactic acid bacteria that survive ensiling may exert probiotic effects in the rumen of cows and thereby potentially enhance animal performance (Weinberg et al., 2004). Weinberg et al. (2003) showed that inoculated lactic acid bacteria survived the ensiling process and increased the pH and VFA concentrations of ruminal fluid, indicating that they may produce conditions that enhance the growth of cellulolytic bacteria and increase supply of precursors for milk production, respectively. Duniere et al. (2015) showed that when added to corn silage, two *Saccharomyces cerevisiae* strains and an *S. paradoxus* strain survived the ensiling process, and increased in counts during the ensiling process, indicating that it could be used to deliver *Saccharomyces* strains to ruminants. When one of the tested strains was subsequently added to dairy cow diets, it improved digestibility and milk production (Jiang et al., 2017).

**Inhibition of spoilage organisms**

Ingestion of yeasts and molds, and mycotoxins produced by molds, has been implicated in causing decreased performance (Undi and Wittenberg, 1996; Whitlock et al., 2000; Santos and Fink-Gremmels, 2014) and various diseases in dairy cows (Driehuis et al., 2018; Ogunade et al., 2018; Queiroz et al., 2018). For instance, Santos et al. (2014) reported that in vitro NDF digestibility and ruminal pH were progressively reduced when corn silage that had been inoculated with a spoilage yeast (*Issatchenkia orientalis*) was included at increasing levels in the diet of dairy cows. Salvo et al., 2015 showed that when corn silage inoculated with *Pichia norvegensis* yeast was fed to dairy cows, yield of 3.5% fat-corrected milk and feed efficiency decreased; the decreases were greater when the silages were exposed to air for 48 h before feeding, rather than feeding them immediately after unloading. Antifungal inoculants can prevent the growth of such performance-constraining fungi in silage. Driehuis et al. (2001), reported reduced mold counts when grass was ensiled with *L. buchneri*. Similarly, Weinberg et al. (2002) observed that ensiling whole crop
wheat with *L. buchneri* inhibited mold growth. In a meta-analysis by our group of 32 studies (Oliveira *et al.*, 2017), ensiling with homofermentative lactic acid bacteria reduced mold counts in ensiled forages. Numerous other studies have shown that yeast and or mold growth can be inhibited by inoculants though few have shown that such reductions can lead to improved animal performance. An exception is the study of Tabacco *et al.* (2011) in which higher milk yield due to lower mold counts was reported when *L. buchneri*-inoculated corn or sorghum silage was fed to dairy cows instead of that inoculated with *L. plantarum*. The authors noted that when the estimated milk yield per megagram of harvested DM of corn and sorghum silage were related to mold count, loss of potential milk production occurred when the mold count exceeded 4 log cfu/g of silage, and milk production was almost halved when the mold count exceeded 8 log cfu/g of silage.

Inoculants that prevent the growth of mycotoxin-producing molds may also prevent mycotoxin contamination of the silage. For instance, Queiroz *et al.* (2012) reported that inoculation of rust-infested corn forage with *P. pentosaceus* and *L. buchneri* reduced mold growth and prevented aflatoxin contamination of the silage.

**Inhibition of pathogenic organisms**

The contamination of silage with pathogens can impair animal performance and health, which increases management and veterinary costs. The inhibitory effects of silage inoculants on various pathogens, such as *Enterobacteria, Listeria, Bacilli* and *Clostridia* have been reviewed by Queiroz *et al.* (2018) and others. In our previous study (Ogunade *et al.*, 2016a), applying *L. plantarum* or *L. buchneri* to alfalfa led to earlier elimination of *E. coli* O157:H7 compared to untreated silage (16 and 100 d, respectively). In a similar study on corn silage (Ogunade *et al.*, 2016b), in which silages were reinoculated with *E. coli* after silo opening, aerated silages that had been treated with *L. buchneri* at ensiling had lower pH and *E. coli* counts than those treated with nothing or *L. plantarum* at ensiling. Similarly, the growth of *Clostridia* can be suppressed by using silage inoculants that rapidly acidify silage and achieve low pH values (< 4.5) that inhibit the bacteria (Queiroz *et al.*, 2018).

Bacteriocin-producing inoculant bacteria have also been used to inhibit the growth of pathogens. *Listeria* was inhibited by applying a combination of *L. lactis* CECT 539 and *P. acidilactici* NRRL N-5627, which produced nisin and pediocin bacteriocins, respectively (Amado *et al.*, 2012). Also inoculation with a bacteriocin-producing strain of *Enterococcus faecium* EF9296 reduced
growth of *E. coli*, enterobacteria, staphylococci and bacillus-like bacteria, mold and listeria on grass silage and improved the fermentation (Marcinakova *et al*., 2008). Consequently, growth of pathogens and spoilage organisms on silage can be prevented or reduced by inoculants that rapidly achieve and maintain acidic conditions during and after ensiling or that produce bacteriocins, which impair their growth (Queiroz *et al*., 2018).

**Summary**

This paper has summarized the modes of action of silage inoculants that contribute to reduced DM losses and increased milk production by dairy cows. More research is needed to characterize the simultaneous effects of inoculants on the silage and ruminal metagenome, metatranscriptome and metabolome to enable more precise descriptions of their modes of action.

**References**


Hu, W., R. J. Schmidt, E. E. McDonell, C. M. Klingerman, and L. Kung. 2009. The effect of *Lactobacillus buchneri* 40788 or *Lactobacillus plantarum* MTD-


STRATEGIC ADDITION OF FIBROLYTIC ENZYMES FOR IMPROVED PERFORMANCE OF LACTATING DAIRY COWS: A REVIEW

Arriola, K. G.

Introduction

Forages are the most important feed source in ruminant nutrition; however, the complexity of their cell wall structure contributes to reduced digestibility. Therefore, several strategies have been proposed to improve forage quality and application of fibrolytic enzymes is one of them. The use of exogenous fibrolytic enzymes (EFE) has been increased over the years as several excellent reviews summarized the effect of fibrolytic enzymes in dairy and beef cattle performance (Beauchemin et al., 2003; Beauchemin et al., 2004; Beauchemin and Holtshausen, 2011). Results among studies are variable and some of the reasons are: they do not use the same type of enzymes or application rate, lactation stage differ between studies, enzyme was applied to different parts of the diet, the experimental design varies a lot, etc. Recent reviews compiled current research and new techniques to improve feed efficiency using fibrolytic enzymes (Meale et al., 2014); also, to evaluate the responses of using EFE in dairy cattle (Adesogan et al., 2014). A recent meta-analysis reviewed and summarized studies to estimate the effect of EFE on dairy cattle performance (Arriola et al., 2017); another meta-analysis evaluated the effects of using EFE in ruminant diets (Tirado-Gonzalez et al., 2017).

The main purpose of this review paper is to summarize the basic knowledge behind exogenous fibrolytic enzymes for better understanding the effects of EFE application in animal diets. The strategies that has been done to improve animal performance using EFE and to propose future directions of research for improving forage digestibility and subsequently animal performance.
Fibrolytic Enzymes, Characteristics, Activities And Mode Of Action

Fibrolytic enzymes

The two main structural polysaccharides in plants are cellulose and hemicellulose (Van Soest, 1994) and they are converted to soluble sugars by cellulases and hemicellulases, respectively. Most of the commercial enzymes in livestock are sourced of fungi such as *Trichoderma reesei*, *Aspergillus oryzae* or *Saccharomyces cerevisiae* or bacteria such as *Bacillus subtilis* and *Streptococcus faecium* (Pendleton, 2000; Beauchemin *et al.*, 2004). These enzymes preparations are commonly described as cellulases or xylanases; however, it also contains secondary enzyme activities like amylases, proteases, esterases or pectinases (McAllister *et al.*, 2001). Despite presence of secondary enzyme activities, most of the commercial labels of enzyme preparations only describe main activity and, primarily cellulases. This issue has been categorized as imprecise enzyme designations (Adesogan *et al.*, 2014) and it might be responsible for significant variation associated with results from previous enzyme studies.

Enzyme activities

Several assays have been developed to measure cellulase and xylanase activities (Wood and Bhat, 1988; Biely *et al.*, 1992). Cellulose is hydrolyzed by 3 major enzymes, 1) endogluanase (EC 3.2.1.4) which hydrolyzes cellulose chains at random to produce cellulose oligomers of varying degrees of polymerization; 2) exoglucanase (EC 3.2.1.9.1) which hydrolyzes the cellulose chain from the non-reducing end producing cellobiose; and 3) β-glucosidase (EC 3.2.1.2.1) which releases glucose from cellobiose and hydrolyzes short chain cello-oligosaccharides from both reducing and non-reducing ends (Beauchemin *et al.*, 2003; Bhat and Hazlewood, 2001; Figure 1). Cellulase activity determination uses carboxymethyl cellulose as the most common substrate which measures endo-β-1,4-glucanase activity (Wood and Bhat, 1988); while exoglucanase and β-glucosidase activities are measured using Avicel and cellobiose as substrates; respectively (Bhat and Hazlewood, 2001).
Figure 1 - Schematic representation of the major enzymes involved in cellulose hydrolysis (Beauchemin et al., 2004).

Xylanase is hydrolyzed by two main enzymes: xylanase (EC 3.2.1.8) and β-1,4 xylosidase (EC 3.2.1.37) (Bhat and Hazlewood, 2001). Xylanases are commonly called endoxylanases and they yield xylooligomers when they hydrolyze xylan whereas, β-1,4 xylosidases yields xylose (White et al., 1993). Xylanase activity uses oat spelt or birchwood xylan as substrates (Bhat and Hazlewood, 2001).

Most studies evaluated the effect of cellulases, and xylanases activities; however, the complexity of plant cell wall may limit its degradation. The mechanism by which lignin limits plant cell wall digestion is the cross-linking of lignin with cell wall polysaccharides through ferulic acid bridges (Jung and Allen, 1995) (Figure 2). One of the most abundant hydroxycinnamic acid in the cell wall of cereal grains is ferulic acid (Kroon et al., 1996) and it is cross-linked to polysaccharides by ester bonds and to components of lignin mainly by ether bonds (Borneman et al., 1991). Some authors suggested that adding esterases could play a role to improve forage degradation in the rumen (Nsereko et al., 2000; Dhiman et al., 2002). During in vitro studies, adding esterase could be beneficial; for example, Eun and Beauchemin (2006) reported an improvement in DM and NDF degradability of alfalfa hay and corn silage by 25% when a combination of xylanase, cellulase and esterase enzymes were applied to the substrates. Krueger et al., (2008) reported that adding an esterase enzyme to tropical grasses enhanced NDF hydrolysis and 96 h in vitro DMD.
Figure 2 - Schematic diagram showing possible covalent cross links between polysaccharides and lignin in walls. a, Direct ester-linkage; b, direct ether-linkage; c, hydroxycinnamic acid esterified to polysaccharides; d, hydroxycinnamic acid esterified to lignin; e, hydroxycinnamic acid etherified to lignin; f, FA ester-ether bridge; g, dehydrodiferulic acid diester bridge; h, dehydrodiferulic acid diester-ether bridge (Iiyama et al., 1994)

Synergistic action of fibrolytic enzymes

The synergy between endo and exoglucanases during solubilization of crystalline cellulose have been demonstrated by some authors (Wood et al., 1989; Klyosov 1990). Synergy between endoglucanase and exoglucanase or different types of exoglucanases or endoglucanases are the most common types of synergy. It has been described by Coughlan et al., (1993) that a complete and efficient hydrolysis of xylan requires the synergistic action of main and side-chain-cleaving enzymes with different specificities. The synergistic effect of combining cellulases and xylanases has led to degradation of bahiagrass hay (Krueger and Adesogan, 2008), oat hulls (Yu et al., 2005), and corn fiber (Kosugi et al., 2002, Murashima et al., 2003); however, the specific types of synergistic interaction in these studies were not disclosed.
**Modes of action of fibrolytic enzymes**

Pre-ingestive effects: There is enough evidence that demonstrates an effect of EFE on animal diet before consumption. One reason to apply EFE to animal diet prior ingestion is to enhance binding of the enzyme to the feed and consequently increase the resistance of the enzyme to further ruminal proteolysis (Fontes et al., 1995). Some authors reported an increase in release of sugars and partially due to partial solubilization of NDF and ADF (Hristov et al., 1996; Krause et al., 1998, Krueger and Adesogan, 2008; Arriola and Adesogan., 2013; Romero et al., 2015). There is evidence that applying EFE to feed could cause structural changes that make the feed more susceptible to further degradation (Nsereko et al., 2000).

Ruminal effects: Beauchemin et al., (2004) summarized some studies where the use of exogenous enzymes at rumen level were more stable than previously expected (Hristov et al., 1998, Morgavi et al., 2000, 2001). In some studies, application of EFE in ruminant diets increased the rate of particle passage (Romero et al., 2013; Feng et al., 1996) but not in others (Beauchemin et al., 1999; Yang et al., 1999) and rarely affected the extent of feed digestion. These positive results from EFE application suggested that is not just a result of substrate solubilization from these enzymes preparations, but rather an increase in total enzyme activity in the rumen than can increase ruminal hydrolytic capacity (Beauchemin et al., 2004; Meale et al., 2014).

McAllister et a. (2001) reported that EFE represents only a fraction of enzyme activity in the rumen considering the capacity of ruminal microbiota to digest fiber, therefore, an increase in fiber degradation cannot be attributed to the EFE direct hydrolysis alone. A better understanding of EFE effect in rumen could be explained by the synergism between EFE and rumen microbes to enhance ruminal cellulose, xylan and corn silage digestion as it was well documented by Morgavi et al (2000).

Post-ruminal: Morgavi et al. (2001) reported that some EFE survive ruminal fermentation and the abomasal environment could influence activity for some time in the small intestine. A previous study by Histrov et al. (1998) demonstrated that adding EFE to the diet of heifers increased xylanase and endoglucanase activity in the duodenum by 30 and 5%, respectively. Adding a xylanase EFE into heifer diets, increased xylanase activity in the large intestine and feces (Hristov et al., 2000). Another study applied EFE to barley grain diets from dairy cows and observed an improvement in total tract digestion which was in part attributed to an improvement in digestibility of fiber and starch in the lower tract (Beauchemin et al., 1999). Therefore, it is still unclear
the practical implication of post-ruminal effect from EFE application (Meale et al., 2014); also, although postruminal effects have been shown, they might only account for a minor component of any positive responses.

**Strategic Supplementation of Fibrolytic Enzyme**

*Application methods of enzymes*

Enzymes has been applied in different parts of the diets, at ensiling time or right before feeding, and results varied a lot within studies. In some studies, enzyme treatment at ensiling has reduced NDF and ADF concentrations and increased NDF digestibility (Kung et al., 1991, Dean et al., 2005) but did not increased milk production (Sheperd and Kung, 1996, Dean et al., 2013). Enzyme application to the forage portion of the diet improved milk yield in some studies (Lewis et al., 1999, Kung et al., 2000) but not in others (Dhiman et al., 2002; Vicini et al., 2003). enzyme application to the TMR improved milk yield (Gado et al., 2009; Mohamed et al., 2013) and feed efficiency in some studies (Arriola et al., 2011a; Holtshausen et al., 2011; Mohamed et al., 2013), while in others did not improved milk yield (Bernard et al., 2010; Peters et al., 2015). A recent meta-analysis reported improvement in milk protein content and protein yield from studies that applied the enzymes to the TMR instead of forage or concentrate (Arriola et al., 2017).

*Screening of enzymes for ruminant diets*

Based on accumulated data from previous studies (Hristov et al., 1996; Krause et al., 1998, Krueger and Adesogan, 2008; Arriola and Adesogan., 2013; Romero et al., 2015); there is sufficient evidence to support the concept that ruminant feed should be pretreated with EFE to exert the pre-ingestive fiber hydrolysis effect that also contributes to increase the release of sugars. These EFE should be tested in vitro at different application rates and with different feed sources to determine effects on NDFD before enzymes are tested in animal trials. A previous study from our group analyzed the enzyme activity from 18 EFE (Table 1) and evaluated the xylanase and endoglucanase activities from 18 EFE at different pH and temperature and concluded that maximum xylanase activity was observed at pH 5.0 for 53% of the EFE and maximum endoglucanase activity was observed at pH 4.0 for 56% of the EFE analyzed (Figure 3), while maximum xylanase and endoglucanase activities were observed at 50ºC for 83% and 81% of EFE, respectively (Figure 4) (Arriola et al., 2011b).
Table 1 - Xylanase, endoglucanase, exoglucanase, and β-glucosidase activities of exogenous fibrolytic enzymes assayed at pH 6.0 and 39ºC (Adapted from Arriola *et al.*, 2011b).

<table>
<thead>
<tr>
<th>EFE</th>
<th>Source</th>
<th>Protein, mg/mL</th>
<th>Xylanase, µmol/min/ml</th>
<th>Endoglucanase, µmol/min/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td><em>Trichoderma reesei</em></td>
<td>84.7</td>
<td>1520</td>
<td>2017</td>
</tr>
<tr>
<td>2A</td>
<td><em>T. reesei</em></td>
<td>143.9</td>
<td>35026</td>
<td>4332</td>
</tr>
<tr>
<td>3A</td>
<td><em>T. reesei</em></td>
<td>93.3</td>
<td>12138</td>
<td>3153</td>
</tr>
<tr>
<td>4A</td>
<td><em>Myceliopthora thermophila</em></td>
<td>27.6</td>
<td>378</td>
<td>540</td>
</tr>
<tr>
<td>5A</td>
<td><em>M. thermophila</em></td>
<td>34.4</td>
<td>5363</td>
<td>491</td>
</tr>
<tr>
<td>6A</td>
<td><em>M. thermophila</em></td>
<td>34.7</td>
<td>7429</td>
<td>7936</td>
</tr>
<tr>
<td>7B</td>
<td><em>Aspergillus niger</em></td>
<td>43.5</td>
<td>2826</td>
<td>1517</td>
</tr>
<tr>
<td>8B</td>
<td><em>A. niger</em></td>
<td>44.2</td>
<td>1601</td>
<td>1735</td>
</tr>
<tr>
<td>9C</td>
<td><em>Aspergillus spp. and T. reesei</em></td>
<td>53.5</td>
<td>2957</td>
<td>755</td>
</tr>
<tr>
<td>10C</td>
<td><em>Humicola spp.</em></td>
<td>31.4</td>
<td>1306</td>
<td>184</td>
</tr>
<tr>
<td>11C</td>
<td><em>Trichoderma spp.</em></td>
<td>90.5</td>
<td>1749</td>
<td>1547</td>
</tr>
<tr>
<td>12C</td>
<td><em>Bacillus subtilis</em></td>
<td>33.1</td>
<td>1853</td>
<td>9</td>
</tr>
<tr>
<td>13D</td>
<td><em>Aspergillus oryzae</em></td>
<td>20.7</td>
<td>91</td>
<td>302</td>
</tr>
<tr>
<td>14D</td>
<td><em>Aspergillus aculeatus</em></td>
<td>58.7</td>
<td>385</td>
<td>629</td>
</tr>
<tr>
<td>15D</td>
<td><em>A. oryzae</em></td>
<td>34.6</td>
<td>7190</td>
<td>78</td>
</tr>
<tr>
<td>16D</td>
<td><em>Humicola insolens</em></td>
<td>27.2</td>
<td>1395</td>
<td>169</td>
</tr>
<tr>
<td>17D</td>
<td><em>T. reesei</em></td>
<td>142.6</td>
<td>685</td>
<td>982</td>
</tr>
<tr>
<td>18E</td>
<td><em>T. reesei</em></td>
<td>20.2</td>
<td>577</td>
<td>843</td>
</tr>
</tbody>
</table>

1EFE= exogenous fibrolytic enzymes, 1A to 18E are 18 enzyme preparations provided by 5 companies with characteristics described in the table.
Figure 3 - The percentage of 18 exogenous fibrolytic enzyme preparations assayed at different pH levels showing maximum xylanase (a) and endoglucanase (b) activities (Arriola et al., 2011b)
A follow up study from our group, evaluated the effect of in vitro NDFD and pre-ingestive hydrolysis of 12 EFE applied to bermudagrass haylage and reported that 9 out of 12 EFE improved NDFD, 5 had greater acetate concentration, 6 had greater propionate concentration and 4 had lower acetate-to-propionate ratio compared with untreated bermudagrass haylage (Table 2), while for pre-ingestive hydrolysis, 3 EFE reduced NDF concentration, and the release of water-soluble carbohydrates, cellobiose, glucose, xylose and ferulic acid was increased by 10, 6, 9, 9, and 8 EFE, respectively (Table 3; Romero et al., 2015).

**Figure 4** - The percentage of 18 exogenous fibrolytic enzymes assayed at different temperature levels showing maximum xylanase (a) and endoglucanase (b) activities (Arriola et al., 2011b)
Strategic addition of fibrolytic enzymes for improved performance of lactating dairy cows: A review

Table 2 - Effect of exogenous fibrolytic enzyme (EFE) addition on in vitro DMD, NDFD and organic acids in bermudagrass haylage (Adapted from Romero et al., 2015).

<table>
<thead>
<tr>
<th>EFE</th>
<th>DMD</th>
<th>NDFD</th>
<th>Acetate (mM)</th>
<th>Propionate (mM)</th>
<th>A:P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>52.0</td>
<td>35.6</td>
<td>33.5</td>
<td>10.4</td>
<td>3.24</td>
</tr>
<tr>
<td>1A</td>
<td>54.4**</td>
<td>39.8**</td>
<td>36.9**</td>
<td>11.7**</td>
<td>3.15*</td>
</tr>
<tr>
<td>2A</td>
<td>54.8**</td>
<td>40.4**</td>
<td>36.2**</td>
<td>11.4**</td>
<td>3.16</td>
</tr>
<tr>
<td>3A</td>
<td>52.7</td>
<td>38.0*</td>
<td>34.3</td>
<td>10.6</td>
<td>3.23</td>
</tr>
<tr>
<td>4A</td>
<td>53.8**</td>
<td>38.5**</td>
<td>36.5**</td>
<td>12.2**</td>
<td>3.03**</td>
</tr>
<tr>
<td>5A</td>
<td>52.4</td>
<td>37.1</td>
<td>36.7**</td>
<td>11.4**</td>
<td>3.19</td>
</tr>
<tr>
<td>9C</td>
<td>52.5</td>
<td>36.2</td>
<td>35.4</td>
<td>10.9</td>
<td>3.18</td>
</tr>
<tr>
<td>11C</td>
<td>54.9**</td>
<td>40.0**</td>
<td>35.2</td>
<td>11.1</td>
<td>3.15*</td>
</tr>
<tr>
<td>12C</td>
<td>53.9**</td>
<td>38.6**</td>
<td>35.4</td>
<td>11.1</td>
<td>3.20</td>
</tr>
<tr>
<td>13D</td>
<td>54.1**</td>
<td>38.9**</td>
<td>36.4**</td>
<td>11.2*</td>
<td>3.27</td>
</tr>
<tr>
<td>14D</td>
<td>52.5</td>
<td>36.3</td>
<td>35.2</td>
<td>11.0</td>
<td>3.22</td>
</tr>
<tr>
<td>15D</td>
<td>53.2</td>
<td>38.5**</td>
<td>34.2</td>
<td>10.6</td>
<td>3.20</td>
</tr>
<tr>
<td>17D</td>
<td>53.2</td>
<td>37.8*</td>
<td>35.1</td>
<td>11.6**</td>
<td>3.09**</td>
</tr>
<tr>
<td>SEM</td>
<td>0.43</td>
<td>0.55</td>
<td>0.57</td>
<td>0.20</td>
<td>0.026</td>
</tr>
</tbody>
</table>

* differed from control P < 0.05; **P < 0.01; A:P= acetate to propionate ratio.

Table 3 - Effect of EFE addition on NDF concentration, release of water-soluble carbohydrates, cellobiose, glucose, xylose and ferulic acid (FER) after pre-ingestive hydrolysis of bermudagrass haylage (Adapted from Romero et al., 2015).

<table>
<thead>
<tr>
<th>EFE</th>
<th>NDF (%)</th>
<th>WSC (%)</th>
<th>Cellobiose (mg/g)</th>
<th>Glucose (mg/g)</th>
<th>Xylose (mg/g)</th>
<th>FER (µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>67.3</td>
<td>22.8</td>
<td>0.00</td>
<td>4.30</td>
<td>0.01</td>
<td>198</td>
</tr>
<tr>
<td>1A</td>
<td>66.0</td>
<td>33.9**</td>
<td>0.59**</td>
<td>8.86**</td>
<td>0.29**</td>
<td>225**</td>
</tr>
<tr>
<td>2A</td>
<td>62.8**</td>
<td>51.8**</td>
<td>1.31**</td>
<td>11.39**</td>
<td>2.15**</td>
<td>391**</td>
</tr>
<tr>
<td>3A</td>
<td>65.3</td>
<td>35.6**</td>
<td>1.05**</td>
<td>10.50**</td>
<td>0.18**</td>
<td>241**</td>
</tr>
<tr>
<td>4A</td>
<td>66.1</td>
<td>29.4**</td>
<td>0.00</td>
<td>8.22**</td>
<td>0.07</td>
<td>210**</td>
</tr>
<tr>
<td>5A</td>
<td>65.9</td>
<td>27.2**</td>
<td>0.24**</td>
<td>7.70**</td>
<td>0.29**</td>
<td>221**</td>
</tr>
<tr>
<td>9C</td>
<td>66.8</td>
<td>26.8**</td>
<td>0.46**</td>
<td>8.80**</td>
<td>0.11**</td>
<td>207</td>
</tr>
<tr>
<td>11C</td>
<td>64.4*</td>
<td>45.4**</td>
<td>2.25**</td>
<td>14.33**</td>
<td>0.36**</td>
<td>285**</td>
</tr>
<tr>
<td>12C</td>
<td>66.7</td>
<td>23.3</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>203</td>
</tr>
<tr>
<td>13D</td>
<td>66.3</td>
<td>22.7*</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>200</td>
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<tr>
<td>14D</td>
<td>66.9</td>
<td>28.9**</td>
<td>0.06</td>
<td>5.33**</td>
<td>0.59**</td>
<td>207</td>
</tr>
<tr>
<td>15D</td>
<td>66.6</td>
<td>31.3**</td>
<td>0.08</td>
<td>4.60</td>
<td>1.13**</td>
<td>340**</td>
</tr>
<tr>
<td>17D</td>
<td>63.7**</td>
<td>58.5**</td>
<td>0.04</td>
<td>23.00**</td>
<td>0.37**</td>
<td>298**</td>
</tr>
<tr>
<td>SEM</td>
<td>0.6</td>
<td>0.43</td>
<td>0.04</td>
<td>0.20</td>
<td>0.02</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* differed from control P < 0.05; **P < 0.01
Effects of exogenous fibrolytic enzymes application on dairy cows

As mentioned before, several excellent previous reviews suggested that the main reasons why some studies do not have the expected results are: studies do not use appropriate stage of lactation, number of animals, inappropriate experimental design, short period of experiment, inadequate statistical power, enzyme selected and correct enzyme activity. Adesogan et al. (2014) explained in detail each of these reasons. A recent meta-analysis was conducted to estimate the effects of EFE in dairy cattle performance (Arriola et al., 2017). This meta-analysis summarized the results from 15 studies with 17 experiments and 36 observations. The selection criteria consisted on studies published in English, have a negative control, use of confined or housed lactating dairy cows, use continuous experimental designs (change-over or Latin squares studies were excluded), use at least one fibrolytic enzyme as a dietary treatment. It was concluded that application of EFE in dairy diets improved milk yield by small amounts (0.82 kg/d), milk protein (0.03 kg/d), and milk lactose (0.05 kg/d) (Table 4); application of EFE to the TMR instead of the forage or concentrate improved milk protein concentration and increasing the experimental duration improved milk protein content and yield.
### Effect of applying exogenous fibrolytic enzymes on the performance of lactating dairy cows across all trials and EFE type (Adapted from Arriola et al., 2017).

<table>
<thead>
<tr>
<th>Item</th>
<th>n(^1)</th>
<th>Control mean</th>
<th>Random effect (and the associated 95% confidence interval)</th>
<th>$P$-value</th>
<th>Heterogeneity $\chi^2$ (Q)</th>
<th>$P$-value</th>
<th>SMD (95% CI)(^3)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg/d</td>
<td>36</td>
<td>23.2 (2.18)</td>
<td>0.22 (-0.07, 0.49)</td>
<td>0.132</td>
<td>58.4</td>
<td>0.008</td>
<td>0.09 (-0.07, 0.24)</td>
<td>0.276</td>
</tr>
<tr>
<td>Milk yield, kg/d</td>
<td>36</td>
<td>36.0 (3.26)</td>
<td>0.83 (0.36, 1.30)</td>
<td>0.001</td>
<td>51.4</td>
<td>0.037</td>
<td>0.25 (0.10, 0.39)</td>
<td>0.001</td>
</tr>
<tr>
<td>FCM, kg/d</td>
<td>26</td>
<td>35.7 (3.43)</td>
<td>0.55 (-0.005, 1.11)</td>
<td>0.052</td>
<td>38.3</td>
<td>0.044</td>
<td>0.16 (-0.003, 0.33)</td>
<td>0.001</td>
</tr>
<tr>
<td>Milk fat, %</td>
<td>36</td>
<td>3.59 (0.41)</td>
<td>-0.05 (-0.09, -0.01)</td>
<td>0.008</td>
<td>30.2</td>
<td>0.697</td>
<td>-0.16 (-0.27, -0.04)</td>
<td>0.006</td>
</tr>
<tr>
<td>Milk protein yield, kg/d</td>
<td>27</td>
<td>1.13 (0.14)</td>
<td>0.03 (0.007, 0.04)</td>
<td>0.007</td>
<td>32.8</td>
<td>0.169</td>
<td>0.20 (0.04, 0.37)</td>
<td>0.014</td>
</tr>
<tr>
<td>Milk lactose yield, kg/d</td>
<td>13</td>
<td>1.77 (0.19)</td>
<td>0.05 (0.02, 0.08)</td>
<td>0.001</td>
<td>7.43</td>
<td>0.828</td>
<td>0.31 (0.13, 0.48)</td>
<td>0.001</td>
</tr>
<tr>
<td>Dry matter digestibility, %</td>
<td>9</td>
<td>68.4 (4.44)</td>
<td>1.36 (-0.14, 2.86)</td>
<td>0.077</td>
<td>16.7</td>
<td>0.033</td>
<td>0.31 (-0.04, 0.66)</td>
<td>0.080</td>
</tr>
<tr>
<td>NDF digestibility, %</td>
<td>9</td>
<td>50.1 (7.45)</td>
<td>2.30 (-0.42, 0.503)</td>
<td>0.098</td>
<td>17.5</td>
<td>0.025</td>
<td>0.31 (-0.05, 0.67)</td>
<td>0.093</td>
</tr>
</tbody>
</table>

\(^1\)Number of comparisons between enzyme treatment and control treatment; \(^2\)RMD= raw mean difference between enzyme and Control treatments (and the associated 95% confidence interval). \(^3\)SMD = Standardized mean difference between enzyme and Control treatments between enzyme and Control treatments (and the associated 95% confidence interval). This SMD was estimated by dividing the RMD by the pooled standard deviation of both treatment groups.
Another recent meta-analysis evaluated the effect of EFE application in diets with different proportions of legumes and grasses on productive performance of lactating dairy cows, sheep and growing beef cattle (Tirado-Gonzalez et al., 2017). A total of 160 in vivo studies (94 EFE treatments/66 controls) were included in the analysis. The authors reported that EFE application to low-forage diets did not affect milk yield or milk components; however, EFE applied to high-forage diets improved milk and milk protein yield (Table 5).

**Table 5** - Effect of using EFE in diets with high and low forage on dairy cow productive performance (Adapted from Tirado-Gonzalez et al., 2017).

<table>
<thead>
<tr>
<th>Variable</th>
<th>F:C ratio &lt;50%</th>
<th>F:C ratio ≥ 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Control</td>
</tr>
<tr>
<td>Dairy cows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI</td>
<td>52</td>
<td>20.3</td>
</tr>
<tr>
<td>Milk yield (kg/d)</td>
<td>52</td>
<td>28.4</td>
</tr>
<tr>
<td>Milk protein (g/d)</td>
<td>49</td>
<td>924.6</td>
</tr>
<tr>
<td>Milk fat (g/d)</td>
<td>49</td>
<td>1136.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>P value</th>
<th>EFE</th>
<th>F</th>
<th>F:C</th>
<th>EFE*F</th>
<th>EFE*F:C</th>
<th>F*F:C</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI</td>
<td>0.003</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.98</td>
<td>0.8</td>
<td>0.0001</td>
</tr>
<tr>
<td>Milk yield</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.15</td>
<td>0.06</td>
<td>0.0001</td>
</tr>
<tr>
<td>Milk protein</td>
<td>0.0001</td>
<td>0.0005</td>
<td>0.0001</td>
<td>0.31</td>
<td>0.06</td>
<td>0.0001</td>
</tr>
<tr>
<td>Milk fat</td>
<td>0.0004</td>
<td>0.015</td>
<td>0.023</td>
<td>0.33</td>
<td>0.18</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

N=number of experiments, EFE= exogenous fibrolytic enzymes; F= forage; F:C forage-to-concentrate ratio

**Future directions for fibrolytic enzymes**

**Role of metagenomics**: Metagenomics is the direct analysis of DNA from environmental samples and has been applied to rumen environment in recent years. A review by Krause et al. (2003) evaluated the methods to improve fiber digestion in the rumen with focus on what has been done to improve fiber digestion with inoculants, fungal treatment, and exogenous enzymes. They reported that genomes of *Fibrobacter succinogenes*, *Ruminococcus albus* and *Ruminococcus flavefaciens* have been sequenced, but the enzymatic mechanism by which these species hydrolyze cellulose is still unclear. The authors suggested to pay closer attention to the actual enzyme requirements of the rumen as it is
necessary to understand the functional genomic in the rumen. A study evaluated the rumen content of a dairy cow using a metagenomics library and identified 9 endo-β-1,4-glucanases, 12 esterases and 1 cyclodextrinase (Ferrer et al., 2005). Hess et al. (2011) assembled 15 uncultured microbial genomes and identified 27,755 predicted carbohydrate-active enzymes. A recent review by Ribeiro et al. (2016) evaluated current methodologies and strategies to identify rumen fibrolytic enzymes and develop effective ruminant fibrolytic feed enzyme cocktails. The authors concluded that the next step for researchers is to develop an effective ruminant fibrolytic feed enzyme cocktail that can act in the rumen as well as synergistically with natural enzymes in the rumen.

**Summary and Conclusions**

This paper summarized the basic knowledge of the main fibrolytic enzymes involved in plant cell wall digestibility, their mode of action, the importance of the enzyme activity as well as the effect of exogenous fibrolytic enzymes on animal performance. Also, emphasized the importance of in vitro screening enzymes as one strategy to be consider before applying these enzymes to the animal diet. More research for in vitro studies will allow to test more enzymes and different forage substrates that will depend on forage availability of each country. This in vitro work could give more alternatives before using animals as the best enzyme candidate might be apply later in animal trials and reduce the cost of testing several enzymes. The number of studies using exogenous fibrolytic enzymes in ruminant diets have been increased in the last years; however, results are still variable because the strategies applied were unsuccessful. Because of the complexity of the plant cell wall, there is the need to select the right enzyme that could degrade cellulose and hemicellulose, but also that could be able to break down cross-links between lignin and cell wall polysaccharides. These new enzymes preparation should report other enzyme activities that could be present and not just xylanases and cellulases activities, since most of the commercial enzymes only focused on xylanase or cellulase activity. Until now, it is still unclear how the mechanism of interaction between rumen microbes and exogenous enzymes is; therefore, more research is needed to clarify this mechanism. One way that could lead to better understanding this mechanism is using more recent approaches such as molecular tools. Therefore, the new target in research is to apply the concept of metagenomics and metatranscriptomics, as these techniques should help to develop new exogenous enzymes preparation that can interact with enzymes from the rumen.
Reference


NEW CONCEPTS ON BALED SILAGE

Borreani, G.; Tabacco, E.1

Introduction

Throughout the world, forage crops are harvested as silage on intensive dairy farms to reduce feeding costs. Among the various silage conservation methods, wrapped bales are commonly used in Europe to preserve the quality of rotational and perennial grass and legume forages (Wilkinson and Toivonen, 2003; McEniry et al., 2007) and have been gaining popularity in the US over the last decade (Han et al., 2006; Arriola et al., 2015). Silage in wrapped bales offers advantages over hay production, such as a more flexible harvest date, less weather dependency and a greater flexibility in ration formulation (Savoie and Jofriet, 2003; Shinners et al., 2009a). Big bale silage is now a well-established conservation system for storing excellent quality forage, and can provide an opportunity to maintain the high feeding value of young herbage (Forristall and O’Kiely, 2005). The making of big bale silage involves several mechanical treatments, ranging from harvesting to storage, to achieve high quality forage in terms of nutritive value and hygienic characteristics. Baled silage is often made from herbage that is wilted more extensively and undergoes more limited fermentation than conventional bunker silage, in order to reduce the number of bales per hectare, the plastic consumption and the costs; moreover, it can be more convenient when fed to animals (Han et al., 2006; McEniry et al., 2007; Tabacco et al., 2013). Unfortunately, the increased dry matter (DM) content also tends to increase fungal growth in wrapped forages (O’Brien et al., 2008; Tabacco et al., 2013), thus increasing hygienic issues as well as the risk of mycotoxicosis (O’Brien et al., 2007; McElhinney et al., 2016) and Listeria contamination (Fenlon et al., 1989; Nucera et al., 2016). Even though the baled silage system is based on a well-established procedure, the fact that the incidence of mold spoilage can be relatively high in baled silage (O’Brien et al., 2008; Borreani and Tabacco, 2010) suggests that the current baled silage making practices can be considered only partially satisfactory (McEniry et al., 2011). In bale silages, more than 40% of the stored forage

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DM is within 120 mm of the film cover, and the reduced total thickness of the combined layers of stretch-film on the bale side, usually 70 μm (four layers) to 105 μm (six layers), could be expected to make individually wrapped bales more susceptible to oxygen ingress (Forristal and O’Kiely, 2005). Even small holes that can occur on farms, due to both mechanical and wildlife factors, can result in quantitative DM losses because of mold growth, especially in conserved forages with higher DM contents (McNamara et al., 2001; Müller et al., 2007). Air penetrating into the silage stimulates aerobic bacteria, yeasts and molds and causes aerobic deterioration (Borreani and Tabacco, 2008; O’Brien et al., 2007). Moreover, under farm conditions, the improper mixing of different parts of the baled silage in the feed-mixer could enhance the final fungal and mycotoxin feed contamination. Farm surveys conducted in Ireland to establish the incidence of fungal growth on baled grass silage have shown that up to 90% of the examined bales had visible fungal growth (O’Brien et al., 2008). Furthermore, Borreani and Tabacco (2010) observed, in a temperate environment, that the development of molds in the peripheral areas of a bale could involve more than 10% of the bale surface, when the conservation period was longer than five months. Therefore, to keep the molded surface as low as possible and to ensure good, stable bale silage conservation, air-tightness has to be maintained for extended conservation periods. A significant reduction in mold growth and an improvement in silage conservation quality are obtained when six or eight layers of film are applied, compared to four (Keller et al., 1998; Müller, 2005). This is more evident when high DM forages are ensiled in wrapped bales and conserved for periods of more than 8 months (especially for alfalfa, Medicago sativa L., Borreani and Tabacco, 2008). More layers of stretch film assure a better airtight cover, but involve prohibitive increases in costs, in plastic usage and in environmental concerns, due to necessity of disposing of the additional plastic (Lingvall, 1995).

Furthermore, the cover can easily be damaged, especially for dry alfalfa, where stems can puncture the plastic film in the corners (shoulders) of the bale, and this leads to large DM and quality losses (Bisaglia et al., 2011). As with all forms of silage, moist bales must be sealed rapidly to deplete the remaining O₂ and initiate fermentation. Sealing was originally performed manually by placing a large plastic bag over each bale (Savoie and Jofriet, 2003). Today, specialized machines (wrappers) provide a seal by applying a stretchable, thin, plastic film around the bale (Savoie and Jofriet, 2003). The wrapping method has not been changed since 1984, when the first bale wrapper model was introduced in Europe by the Norwegian company Kverneland-Underharg (Anonymous, 1995). Two
main types of round bale wrapper are currently available: the rotating table and the rotating arm (Lingvall, 1995). Combined baler-wrapper units that can only wrap in the field have become common (Forristall and O’Kiely, 2005).

However, the stretch polyethylene wrapping system has shown some limits, with regards to sealing efficiency (Jacobsson et al., 2002), concerning the high permeability to oxygen of stretch films (Borreani and Tabacco, 2008; 2010) and the non-uniform distribution of plastic films between the ends and the curved surface of the bale (Borreani et al., 2007). These problems have lead to undesirable air exchanges over the conservation period, and it has been suggested that an increasing number of plastic film layers is required. For these reasons, great efforts have been made to reduce the possibility of damage to the plastic and of air ingress through the plastic cover during the conservation period.

Bale silage fermentation

The wilting of forages, prior to wrapping them as baled silage, is an important part of the baled silage production system, since it reduces the number of bales per hectare, as well as the amount and cost of the stretch film used for wrapping. At a farm level, a greater DM content at baling than 35% is commonly found, and this increases the risk of molding and heating that are mainly related to difficulties in the exclusion of oxygen (Han et al., 2006). A high DM content leads to weak fermentation, due to a lack of moisture for active fermentation, and to sugar consumption by aerobic microbes and plant activity to deplete the high amount of oxygen trapped in silages. Both the rate and the extent of silage fermentation are affected by the forage DM content at baling (Han et al., 2014). A difference of around 0.5 pH units lower for chopped bunker silages than for wrapped bales, in relation to the DM content in alfalfa and Italian ryegrass (Lolium multiflorum Lam.) farm silages in northern Italy, is reported in Figure 1. The DM content at baling and the type of crop influence the fermentative profiles of the bales (Figure 2; Table 1). Commonly wrapped bales present lower lactic acid and volatile fatty acid contents than silages in bunker silos, due to the lack of release of soluble sugars by chopping (Muck and Shinners, 2001). Muck and Shinners (2001) reported that baleage does not ferment as much as chopped silage, and the DM should be 5 to 10 percentage units higher to prevent clostridial fermentation. The lactic acid content for a greater DM content than 50% is found, in most cases, to be below
20 g/kg DM. A low moisture content, a low lactic acid content and a high pH can result in mold covered baled silage (O’Brian et al., 2007; Borreani and Tabacco, 2008), therefore preservation mainly depends on a low water activity and perfect anaerobic conditions rather than the silage acids, as is the case with more moist silages. Bales with a greater butyric acid content than 5 g/kg DM have been found in baleage with a DM content of up to 45% (Figure 3). Although fermentation in heavily wilted forage can be weak and the pH can be high, well-sealed baleage of alfalfa and perennial ryegrass has been shown to maintain a greater nutritive value than hay (Han et al., 2004; Han et al., 2006).

![Figure 1 - Relationship between silage pH and DM content of alfalfa and Italian ryegrass silages conserved in bunker silos (dotted regression line) and in wrapped bales (continuous regression line) on farms in northern Italy.](image-url)
Figure 2 - Scatter plot of lactic acid versus DM content in well conserved wrapped bales of alfalfa, Italian ryegrass and permanent meadow on dairy farms in northern Italy.

Figure 3 - Scatter plot of butyric acid versus DM content in conserved wrapped bales of alfalfa, Italian ryegrass and permanent meadow on dairy farms in northern Italy (n. = 299).
### Table 1 - Effect of DM content and crop type on fermentative characteristics (g/kg DM or otherwise stated) of well conserved bale silages.

<table>
<thead>
<tr>
<th>Forages</th>
<th>DM content</th>
<th>pH</th>
<th>Lactic acid</th>
<th>Acetic acid</th>
<th>Butyric acid</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>35 to 40%</td>
<td>4.32-5.17</td>
<td>23.8-51.0</td>
<td>10.3-27.0</td>
<td>&lt; 0.01-1.9</td>
<td>Borreani <em>et al.</em>, 2007</td>
</tr>
<tr>
<td></td>
<td>4.49-4.62</td>
<td>44.7-46.4</td>
<td>15.3-21.3</td>
<td>0.2-0.8</td>
<td></td>
<td>Hancock and Collins, 2006</td>
</tr>
<tr>
<td></td>
<td>5.27-6.08</td>
<td>9.9-37.0</td>
<td>3.5-16.9</td>
<td>&lt; 0.01-0.6</td>
<td></td>
<td>Borreani and Tabacco, 2008</td>
</tr>
<tr>
<td></td>
<td>4.80-4.93</td>
<td>13.3-19.6</td>
<td>3.5-6.6</td>
<td>0.4-0.8</td>
<td></td>
<td>Hancock and Collins, 2006</td>
</tr>
<tr>
<td></td>
<td>5.31-6.14</td>
<td>2.1-6.8</td>
<td>1.2-7.8</td>
<td>&lt; 0.01-0.3</td>
<td></td>
<td>Borreani and Tabacco, 2010</td>
</tr>
<tr>
<td>Italian ryegrass</td>
<td>30 to 40%</td>
<td>4.21-4.63</td>
<td>22.2-90.1</td>
<td>9.9-31.6</td>
<td>&lt; 0.01-3.5</td>
<td>Bisaglia <em>et al.</em>, 2011</td>
</tr>
<tr>
<td></td>
<td>4.57-5.73</td>
<td>12.6-63.2</td>
<td>1.4-17.1</td>
<td>&lt; 0.01-3.5</td>
<td></td>
<td>Borreani and Tabacco, unpublished</td>
</tr>
<tr>
<td></td>
<td>5.52-6.51</td>
<td>&lt; 0.01-11.8</td>
<td>&lt; 0.01-6.1</td>
<td>&lt; 0.01-0.1</td>
<td></td>
<td>Borreani and Tabacco, unpublished</td>
</tr>
<tr>
<td>Permanent meadow</td>
<td>30 to 40%</td>
<td>4.11-4.58</td>
<td>28.8-79.4</td>
<td>8.4-25.1</td>
<td>&lt; 0.01-3.2</td>
<td>Borreani and Tabacco, unpublished</td>
</tr>
<tr>
<td></td>
<td>4.66-5.72</td>
<td>2.4-46.4</td>
<td>&lt; 0.01-12.0</td>
<td>&lt; 0.01-5.7</td>
<td></td>
<td>Borreani and Tabacco, unpublished</td>
</tr>
<tr>
<td></td>
<td>5.96-6.32</td>
<td>1.4-8.9</td>
<td>&lt; 0.01-3.4</td>
<td>&lt; 0.01</td>
<td></td>
<td>Tabacco <em>et al.</em>, 2013; Muller <em>et al.</em>, 2011</td>
</tr>
<tr>
<td>PM with timothy*</td>
<td>30 to 40%</td>
<td>4.65</td>
<td>38.3</td>
<td>11.3</td>
<td>0.8</td>
<td>Muller <em>et al.</em>, 2007</td>
</tr>
<tr>
<td></td>
<td>5.55</td>
<td>5.5</td>
<td>2.0</td>
<td>2.0</td>
<td>&lt; 0.01</td>
<td>Muller <em>et al.</em>, 2007</td>
</tr>
<tr>
<td></td>
<td>5.72</td>
<td>0.4</td>
<td>0.7</td>
<td>&lt; 0.01</td>
<td></td>
<td>Muller <em>et al.</em>, 2007</td>
</tr>
</tbody>
</table>

* PM = permanent meadow.
New Technical Solutions To Improve Bale Silage Quality

The technical solutions that have recently appeared on the market involve the following aspects: improved bale densities, especially for high DM content silages; increased uniformity of the plastic distribution over the bale surface; reduced plastic permeability to oxygen. The rapid development in wrapping bale technology has led to a great improvement in the ensiling process, and this has been achieved by increasing bale densities with round balers equipped with a crop-cutter (Shinners, 2003; Borreani and Tabacco, 2006), reducing the working times with combined baler-wrapper machines (Münster, 2001), and improving the uniformity of the plastic distribution on the bale surface with a new-concept 3D wrapping system (Borreani et al., 2007) or round balers equipped with film-tying attachments to replace the standard net-tying system with a film tying system, in order to improve the airtightness of the coverage on the bale curved surface (Bisaglia et al., 2007).

**Improving bale density**

Since the 2000’s, forage crops formed in round bales for silages generally have undergone little if any size reduction during harvesting (Shinners, 2003). Herbage is rolled during baling, but this does not give the bale a high density and it makes oxygen exclusion more difficult. Silage compaction has been improved by reducing the chop-length of herbage, with denser bales resulting in lower handling and transport costs (Ohlsson, 1998).

Round balers with a cutting system behind the pickup are available on the market and could provide the following advantages: density increases of up to 15%, with subsequent improvements in baler productivity and silage quality (Borreani and Tabacco, 2006), and bales are more readily processed by TMR mixer-feeders (Shinners, 2003). The technique of cutting the herbage into shorter lengths on entry to the bale chamber could facilitate the release of plant sugars, and thus provide an aid to obtaining a better bale density (Shinners, 2003). Borreani and Tabacco (2006) observed, on alfalfa round bales, that the chopping system increased the percentage of stems that were shorter than 10 cm, from 14 to 38% on a DM basis, compared to unchopped bales. This reduction in particle size resulted in a reduction of the power requirements and loading times during feed mixer operations (Bisaglia et al., 2002). Increases in big bale weight, due to the chopping device, have been reported in several researches (Ohlsson, 1998; Bisaglia et al., 2002; Borreani and Tabacco, 2006) and are summarized in Table 2.
Other advantages are that the dispersion of additives within a bale is likely to be improved in bales made from precut forage (Lingvall, 1995).

**Table 2 - Effect of cutting device applied to baler in increasing bale weight.**

<table>
<thead>
<tr>
<th>Forages</th>
<th>Baler</th>
<th>DM content (%)</th>
<th>Bale weight increase due to cutting device</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>fixed chamber</td>
<td>35.0</td>
<td>2.5</td>
<td>Borreani and Tabacco, 2006</td>
</tr>
<tr>
<td></td>
<td>fixed chamber</td>
<td>60.5</td>
<td>4.7</td>
<td>Borreani and Tabacco, 2006</td>
</tr>
<tr>
<td></td>
<td>fixed chamber</td>
<td>50.7</td>
<td>7.8</td>
<td>Bisaglia <em>et al.</em> (2001)</td>
</tr>
<tr>
<td></td>
<td>variable-chamber</td>
<td>50.7</td>
<td>14.3</td>
<td>Bisaglia <em>et al.</em> (2001)</td>
</tr>
<tr>
<td></td>
<td>variable-chamber</td>
<td>43.1</td>
<td>3.0</td>
<td>Borreani and Tabacco, 2002</td>
</tr>
<tr>
<td>Italian ryegrass</td>
<td>fixed chamber</td>
<td>33.6</td>
<td>3.3</td>
<td>Bisaglia <em>et al.</em>, 2001</td>
</tr>
<tr>
<td></td>
<td>variable-chamber</td>
<td>33.6</td>
<td>8.7</td>
<td>Bisaglia <em>et al.</em>, 2001</td>
</tr>
<tr>
<td>Permanent meadow</td>
<td>variable-chamber</td>
<td>47.3</td>
<td>8.4</td>
<td>Borreani and Tabacco, 1999 unpublished data</td>
</tr>
<tr>
<td>Barley</td>
<td>variable-chamber</td>
<td>32.6-42.7</td>
<td>7 to 9%</td>
<td>Ohlsson, 1998</td>
</tr>
</tbody>
</table>

**Increasing the uniformity of the plastic distribution**

Traditionally, four layers of polythene are applied in two subsequent and complete rotations of a bale, with an overlap of 50% between layers. A significant reduction in mold growth and improvement in silage conservation quality can be obtained when six or eight layers of film are applied rather than four (Keller *et al.*, 1998). Increasing the layers with a conventional wrapping system causes a non-uniform distribution of the plastic film between the end and the side of the bale, with a waste of plastic film, due to the higher proportion of plastic distributed on the flat ends (Figure 4 – conventional wrapper). To increase the uniformity of plastic distribution, two different solutions have recently appeared on the market: the selective 3D wrapper and round-balers equipped with a tying system to secure large round bales with polyethylene tying-film in the baler chamber.

The commercial availability of a new concept of selective wrapper (3D), alone or mounted onto the rear of a baler, offers an improved film application method for round bale silage. It was first proposed as a prototype by the Vicon-Kverneland Group (Bisaglia *et al.*, 2003). The new-concept selective 3D wrapper is based on a biaxial rotation of film applicators (Figure 5), and it is of great interest because it reduces the amount of plastic used per bale, while improving the uniformity of the plastic distribution on the surface and
increasing the number of layers in the areas that are most at risk to damage (Borreani et al., 2007). Borreani et al. (2007) reported that the uniformity of the plastic distribution over the bale is increased, in comparison to a conventional wrapper, and this system allows at least seven layers to be applied over the whole bale surface with less plastic than the amount utilized by a conventional wrapper to wrap a bale in six layers (a 3D wrapper utilizes from 0.862 to 0.976 kg of plastic per bale vs. a conventional wrapper which consumes 1.013 kg of plastic per bale for 6 layers) (Figure 4). In a conventional wrapper bale, which is nominally wrapped with four layers of plastic film, the flat ends have as many as 16-20 layers in the center, a number which gradually decrease to four layers at the outer edge and on the curved surface. The 3D wrapping method has improved the bale silage technique by reducing the amount of plastic on the flat ends, without lowering the fermentation and conservation quality of silages. This improvement in the distribution of the plastic over the bale surface reduces mold development, and protects the bale edges from the damage of alfalfa stems (Borreani et al., 2007). The new-concept wrapper produces well-shaped bales that do not lose their shape during storage.

**Figure 4** - Number of layers at the end and at the side of bales for the two wrapping systems and two different layer settings. The numbers on the horizontal axis are the distances (mm) around the median outer edge of the bale, starting from a corner (Adapted from Borreani et al., 2007).
Some new-generation balers that have recently come onto the market are equipped with tying systems that allow a bale to be secured in the press chamber using twine, net, or polyethylene film. Bisaglia et al. (2011) investigated the possibility of replacing the standard net used to secure bales with polyethylene film (Figure 6). They found that film-tying reduced the mold-covered surface on the curved side of the bales, and that it could represent an interesting alternative to net-tying when preparing round bales for silage. The same authors, concluding their work, pointed out the need to obtain a better bale-edge covering to further reduce the possibility of mold growth over the conservation period.

As a result of their research, a film tying system was developed to better cover the bale edges. Tabacco et al. (2013) studied the possibility of reducing mold growth on the surface of low-moisture baled silage of grass-legume mixtures for a long conservation period (8 months), without increasing plastic costs, by replacing polyethylene net with polyethylene tying-film to secure large round bales in the baler chamber. The high DM content of the silages
restricted fermentation and resulted in low concentrations of acids, with pH values in the inner part of the bale ranging from 5.41 to 5.70. The tying film was well distributed over the curved side and over the edges of the bales (Figure 7), and did not show any signs of damage due to mechanical operations (ejection, handling, wrapping). The use of tying film, compared to net, led to a reduction in the number of holes and an improvement in the anaerobic status of the baled silage, even with just four layers of stretch-film, and resulted in a decrease in mold counts and visible mold growth over the bale surface (Table 3). In conclusion, they reported that with similar costs for plastic and the same amount of plastic used to secure the bale with net and wrap it in four layers of stretch-film, it is possible, using a tying film of 16 μm in the baler chamber, to obtain more than six effective layers of plastic on the curved side and on the edges of the bale, and therefore to reduce the risk of cover puncturing and the incidence of mold growth over the bale surface to a similar level to that of baled silage wrapped in six layers of polyethylene and secured with net. Furthermore, increasing the number of stretch-film wraps from four to six, while using a polyethylene tying-film, not only increased the actual numbers of layers on the round side and edges of the bale, but also reduced the mold growth over the bale surface of high wilted silage to a lower value than 1%, without increasing the total plastic usage and costs, compared with bales secured with polyethylene net.

Figure 6 - Bale tied with film after ejection from the baler chamber waiting to be wrapped.
**Figure 7** - Total plastic thickness at the side and end of the bale for the tying film compared to the net tying system and two different layer settings (four vs. six). The numbers on the horizontal axis are the distances (mm) around the median outer edge of the bale. N, tying net; F, tying film; 4, four layers of stretch-wrap; 6, six layers of stretch-wrap (from Tabacco et al., 2013).

**Table 3** - Bale weight, bale density, plastic consumption, plastic thickness on the curved side of the bale, plastic damage, surface covered by mold, DM losses, and costs of plastic in relation to the tying method and the number of plastic layers applied (from Tabacco et al., 2013).

<table>
<thead>
<tr>
<th>Items</th>
<th>Tying Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Net-tying</td>
</tr>
<tr>
<td>Net/film per bale for tying (g)</td>
<td>216</td>
</tr>
<tr>
<td>Stretch-film wrap per bale (g)</td>
<td>901</td>
</tr>
<tr>
<td>Total plastic per bale (g)</td>
<td>1117</td>
</tr>
<tr>
<td>Thickness of stretch-film wrap (μm)</td>
<td>79</td>
</tr>
<tr>
<td>Thickness of tying film (μm)†</td>
<td>-</td>
</tr>
<tr>
<td>Micro-holes in the plastic cover (n)</td>
<td>14</td>
</tr>
<tr>
<td>Surface covered by mold (%)</td>
<td>25.3</td>
</tr>
<tr>
<td>DM losses (g/kg DM)</td>
<td>56</td>
</tr>
<tr>
<td>Cost of the tying film/net (€/bale)</td>
<td>0.81</td>
</tr>
<tr>
<td>Cost of the stretch-film wrap (€/bale)</td>
<td>2.92</td>
</tr>
<tr>
<td>Plastic cost per bale (€)</td>
<td>3.72</td>
</tr>
<tr>
<td>Plastic cost per tonne of harvested DM (€)</td>
<td>10.97</td>
</tr>
</tbody>
</table>

**Oxygen barrier films to wrap bale silages**

Borreani and Tabacco (2010) observed, in a temperate environment, that the development of molds in the peripheral areas of the bale could involve more than 10% of the bale surface, when the conservation period is longer than 5
months. Even though the baled silage system is based on a well-established procedure, the fact that the incidence of mold spoilage can be relatively high (O’Brien et al., 2008; Borreani and Tabacco, 2010) suggests that the current baled silage making practices should be considered only partially satisfactory (McEniry et al., 2011). Although the usual recommendation to farmers is to use six nominal layers of stretch film to provide a valuable safety margin, many authors (Lingvall, 1995; Keller et al., 1998; Paillat and Gaillard, 2001) have demonstrated that, when using commercial PE stretch films, the amount of oxygen that diffuses into the bale during storage, and consequently the amount of visible molding that occurs, can only be reduced by applying more film layers, but, as previously stated, this requires longer wrapping times, as well as an increase in costs and environmental concerns. Improving the oxygen impermeability of stretch film has thus been identified as one of the most effective ways of obtaining significant improvements in the conservation quality of baled silage (Borreani and Tabacco, 2008, 2017). New plastic manufacturing technologies, coupled with new low oxygen permeability polymers that can be coextruded with PE, offer the possibility of producing multilayer stretch films for the wrapping of bale silages at costs that are competitive with those of the conventionally used PE on farms (Borreani and Tabacco, 2005). Furthermore, these new films could solve the problems that have restricted the application of wrapping technology to silage with a higher DM content than 60% (Borreani and Tabacco, 2008, Borreani et al., 2009). Polyethylene (PE) has been used for many years for the industrial production of plastic films for wrapping bales because of its suitable mechanical characteristics and low costs. Most plastic films for stretch-wrap silage production are made of coextruded, linear low-density polyethylene, and are 25 μm thick before being stretched 50% or more during application. The high O₂ permeability of PE films seems to be one of the main drawbacks of wrapped silage, especially for conservation periods longer than six months (Borreani and Tabacco, 2008).

A new oxygen barrier stretch film, with an 18-fold lower oxygen permeability than that of the PE stretch film commonly used on farms, has recently become available in Italy. This new material may solve the problems that have restricted the application of the wrapping technology to extremely wilted alfalfa silage, without increasing the amount of plastic applied (Borreani and Tabacco, 2008, Borreani et al., 2009). Furthermore, Borreani and Tabacco (2008) showed the possibility of using four layers of an oxygen barrier film instead of six layers of a PE film, without increasing the risk of mold damage on baled alfalfa silage. Paillat and Gaillard (2001) reported that stretching to
60% reduced the thickness from 25 to 19 μm, accelerated film wear, and on average decreased the service life of a film by 48%. Furthermore, Hancock and Collins (2006) reported that the oxygen permeability of a single layer of PE film stretched to 150% of its original length increased to values ranging from 7750 to 9810 cm³/m²/d, according to the manufacturing process.

Since the oxygen impermeability of stretch film seems to have a great effect on reducing the spoilage of bale silage and DM losses, it is crucial to define the level of oxygen impermeability of the stretch film that could improve the conservation quality of wrapped bales, without increasing plastic consumption. Some polymers that are different from PE, such as polyamides (PA) and ethylene-vinyl alcohol (EVOH), offer excellent barrier properties to oxygen, combined with good mechanical characteristics (puncture resistance and stretch properties), and they are suitable for blown co-extrusion with PE (Borreani and Tabacco, 2017). These polymers are also characterized by the absence of chlorine in their molecules, thus reducing the risk of dioxin production if they are burned. EVOH combines the excellent barrier properties of polyvinyl alcohol to oxygen with those of PE against water. The second group of polymers is PA, which is also known as nylon, and it was first produced in 1935 as a synthetic replacement for natural silk. PA has a good thermal stability, but an oxygen permeability that is about 30 times greater than that of EVOH. The oxygen permeabilities of these polymers, for a 1 μm thickness film under standard conditions (23°C, 1 bar, and 65% RH), are 1380 for PA and 38 for EVOH, versus 178,000 cm³ m⁻² d⁻¹ for low-density PE. Another important factor that is often neglected is the influence of temperature on the permeability coefficient, which increases exponentially with temperature. This leads to a 7.4-fold increase in permeability when a film heats to 70°C in the sun (Daponte, 1994). Daponte (1992) also reported that the oxygen permeabilities of low quality to high quality PE silage films are close to each other in the thickness range because a nearly linear relationship exists between permeability and film thickness.

A first attempt at using co-extruded oxygen barrier (OB) stretch-wrap films with baled silage was described in detail by Borreani and Tabacco (2005 and 2008). This first generation of OB stretch-wrap film was developed by means of the co-extrusion of LDPE with PA. The results showed an evident effect of the film type and number of layers on the percentage of bale surface covered by mold, with lower values than 15% in the bales wrapped with at least 4 layers of OB film conserved for longer periods than eight months. Storage DM losses were also affected by the type of film that was used and by the number of layers applied, with consistently lower values in OB silages for at least four layers
of film (Borreani and Tabacco, 2008). It was concluded that the new stretch film could be used to conserve silage for more than eight months, without any decrease in the conservation quality or prohibitive increases in costs and plastic usage.

Further improvements in oxygen impermeability for films used to cover bunker silage were obtained by co-extruding a thicker layer than 2 μm of a special grade of EVOH between two or more layers of PE (Borreani et al., 2009). The oxygen impermeability of the new high oxygen barrier (HOB) film was improved by about 21- and 374- fold, compared to that of first generation of OB and standard PE films, although it maintained similar mechanical properties to those of the best performing PE stretch film (Table 4).

Table 4 - Characteristics of three stretch films (25 μm thick) with different oxygen impermeability. The measurements were conducted on new film before stretching (data from Borreani and Tabacco, 2010).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Plastic film</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PE</td>
</tr>
<tr>
<td>Oxygen permeability at 23°C†</td>
<td>7120* (cm²/m²/24 h at 0.1 MPa and 65% RH);</td>
</tr>
<tr>
<td>Oxygen permeability at 50°C†</td>
<td>21360*</td>
</tr>
<tr>
<td>Puncture resistance to probe penetration (mm)</td>
<td>20.8</td>
</tr>
<tr>
<td>Tensile strength at break, MD (MPa)</td>
<td>62.0</td>
</tr>
<tr>
<td>Tensile strength at break, TD (MPa)</td>
<td>37.6</td>
</tr>
<tr>
<td>Elongation at break, MD (%)</td>
<td>534</td>
</tr>
<tr>
<td>Elongation at break, TD (%)</td>
<td>1015</td>
</tr>
</tbody>
</table>

HOB, high barrier film; OB, medium barrier film; MD, machine direction; PE, standard polyethylene film; TD, transverse direction. † From the barrier database.

When tested in research trials performed at a farm scale, the HOB stretch films with improved oxygen impermeability were effective in reducing the DM losses during conservation to values of around 2% for alfalfa baled silage with a DM content ranging from 55 to 65% (Figure 8).
Other authors have reported DM losses of 6% (Hancock and Collins, 2006), or of 7% of the total harvested DM (Shinners et al., 2009b; Borreani and Tabacco, 2008) for alfalfa silage baled at similar DM contents and wrapped with standard PE stretch films. The improved oxygen impermeability has also had a remarkable influence on the evolution of the surface covered by mold: the higher the barrier properties of the plastic film utilized to wrap the bales are, the greater the reduction in mold growth on the bale surface over the conservation period (Figure 9). Owing to the possibility of using less plastic and a lower number of layers on the bale surface, the next research steps shall be focused on establishing bale management tips which could provide greater protection from mechanical damage and reduce the risk of plastic puncturing during handling and conservation (which currently can only be provided by increasing the amount of plastic applied).
Plastic bale damage

Bales are usually wrapped in the field immediately after baling and before being transported to the storage site and invariably stored outdoors (McNamara et al., 2001). If the integrity of a stretch film is damaged during storage, the subsequent ingress of oxygen will permit the growth of filamentous fungi and other micro-organisms, thus resulting in extensive quantitative and qualitative losses (McNamara et al., 2001; Kawamoto et al., 2012). The plastic stretch-film surrounding baled silage is prone to damage during storage, prior to being fed to livestock, by many vertebrates. Damage by birds (McNamara et al., 2002) and by rats (Kawamoto et al., 2012) has been reported to be the most frequent on farms, while that caused by cats, dogs and other farm livestock is comparatively limited (McNamara et al., 2002). Direct physical barriers to bird access, as opposed to scaring devices, such as the use of nets securely positioned 1 m above and beside the bales, appear to be the most reliable way of preventing damage (McNamara et al., 2002). Whole cereal baled silages result to be particularly attractive to rats, which could easily damage bales stored under a masking situation (Kawamoto et al., 2012). It is suggested that creating open spaces between the bales and not covering bales with plastic sheets reduces the number of hiding places that are available for rats, thereby decreasing their potential damage.
New possibilities of ensiling fine chopped material in wrapped bales

New machines that integrate a baler and a wrapper together are now available on the market, and they increase productivity and reduce operation costs compared to the use of two separate machines. In recent years, new combined baler-wrapping machine have been developed with the aim of baling fine chopped material or fine-particle biomass and wrapping them with stretch plastic. Many of these new machines have adopted some or all of the technical solutions described above, such as film tying in the compression chamber and two 3D film dispensers to speed up the wrapping operation and increase the homogeneity of the plastic distribution over the bale.

The first attempt to assemble a baler with its own wrapping device were made in Finland (Anonymous, 1992), while the first machine that was able to bale fine chopped material was developed in Norway (Anonymous, 1990), and it was designed to be top-filled by a forage chopper (Figure 10).

![Figure 10](image)

Shito et al. (2006) reviewed the development of roll balers for chopped materials made at the beginning of the current century. Weinberg et al. (2011) described and presented the results of a commercial established process that is based on the production of dense bales of silage under high pressure, followed by packing and wrapping with 8 to 9 layers of polyethylene stretch film. This technology has been successfully used for the preservation of high-moisture by-products stored with dry feeds (Miron et al., 2012; Shaani et al., 2015),
or as completely finished total mixed rations (TMR) for lactating dairy cows (Wang et al., 2010; Weinberg et al., 2011). Ensiling TMR is becoming a wide-spread practice, and the advantages attributed to it include the supply of homogeneous feed over time to the animals, labor savings during preparation and the opportunity to include otherwise perishable moist by-products (Weinberg et al., 2011; Shaani et al., 2015). Weinberg et al. (2011), Miron et al. (2012) and Shaani et al. (2015) indicated that the DM density of a bale was above 400 kg/m³, which is more than twice the DM density of silage in a bunker silo (Savoie and Jofriet, 2003), a fermentation process takes place during storage even for already ensiled material, and the forage quality can be maintained outdoors for a long period of time, even under hot summer conditions. Furthermore, the preserved TMR had improved aerobic stability, compared with that of the fresh TMR.

As mentioned above, forage crops conserved as silage in round bales undergo a slight reduction in particle size during harvest (Muck, 2006), are baled at a higher DM concentration, are stored at a lower bulk density, and are less fermented than silages stored in bunker silos (Weinberg et al., 2011). In the last few years, stationary compactor machines have been developed to suitably conserve, apart from finished TMR, fine chopped forage or ground grain that were previously only conserved in stack silos, thus allowing them to be stored until needed and to be transported like any other commodity. Many chopped forages, such as whole corn silage, whole ear corn silage and whole crop soybean silage, could be profitably preserved in wrapped bales as feeds for lactating cows on small-medium sized farms, as could fine chopped corn stover, rice straw and other lignocellulosic wastes, as ensiled biomass that could be used to produce bioenergy and biofuels (Borreani G. and Tabacco E., University of Turin, pers. com., 2017; Anonymous, 2017).

**Summary**

The technical and research innovations developed over the last few decades in the field of wrapped bales provide an opportunity to successfully plan farm silage making, while maximizing silage quality and minimizing losses. The reported new technical solutions will improve the feasibility of producing high DM content baleage and of maintaining the nutritional and microbial quality of the forage, while reducing the cost per tonne of stored DM. The improvement in the uniformity of baled silage, in terms of nutritional and hygienic quality, is
a priority to make this relatively new technique successful, a technique, which, when used properly, could increase the technical efficiency and economic sustainability of dairy production systems.

References


McEniry, J., P.D. Forristal, and P. O’Kiely. 2011. Gas composition of baled grass silage as influenced by the amount, stretch, colour and type of plastic stretch-film used to wrap the bales, and by the frequency of bale handling. Grass Forage Sci. 66: 277-289.


THE INTERFACE OF FORAGE HARVESTER, KERNEL PROCESSING, AND DAIRY COW PERFORMANCE

Salvati, G. G. S.; Nussio, L. G.

Introduction

Whole-plant corn silage (WPCS) is the predominant forage used by the dairy industry in the USA (Martin et al., 2017) and in Brazil (Bernardes and Rêgo, 2014). The WPCS is energy forage with great dry matter (DM) yield per hectare from kernel and stover fractions, which are high in starch and NDF contents, respectively (Dias Junior et al., 2016).

The kernel fraction, composed of approximately 72% starch (DM basis; Huntington, 1997), represents nearly 45% of the whole-plant DM (Philippeau and Michalet-Doreau, 1998) and more than 50% of the energy in WPCS (calculated using NRC, 2001). Total-tract starch digestibility (TTSD) of WPCS, however, ranges from about 80 to 98% in lactating dairy cows fed WPCS-based diets (Ferraretto and Shaver, 2012a). The digestibility of the starch component of WPCS is influenced primarily by kernel processing and length of storage (Ferraretto and Shaver, 2012a,b; Ferraretto et al., 2015). The interest in improving starch digestibility in WPCS by lactating dairy cows has been stimulated due to the relative high cost of cereal grains in the market.

Since then different corn silage processing has been implemented on some of the self-propelled forage harvesters (SPFH) being used on farms. Changes include shredlage processors, shredder rolls, conventional processors with greater roll speed differential, and inter-meshing disc processors (Salvati et al., 2015). Additionally, there has been a lot of recent interest, especially related to the feeding of increased levels of WPCS in the diets, about setting the forage harvester for a longer theoretical length of cut (TLOC) with the aim of increasing the particle length of WPCS. To harvest WPCS, greater TLOC settings (≥19 mm vs. < 10 mm) are used on customized forage harvesters that are equipped with kernel-processing rolls in an attempt to maintain or improve fiber effectiveness as the stover is also crushed by the rolls (Johnson et al., 2003). However, we still are lacking basic scientific to support decision.

In Brazil, most dairy farmers harvest the corn crop with pull-type forage harvester (PTFH) 90.4% versus 9.6% SPFH (Bernardes and Rego, 2014).
Brazilian PTFHs do not have any kind of kernel processor and it is critical because the most cultivated hybrids have flint endosperm (Correa et al., 2002) which is more difficult to be broken. Studies that show the magnitude of gain in TTSD and milk yield in WPCS with flint endosperm hybrids should be stimulated more often.

**Harvesters and kernel processors**

Crop processing systems are widely used in Europe and their use is rapidly growing in North America (Shinners et al. 2003). The fully active crop processors are the most used in the harvesters. It usually consists of two counter-rotating rolls positioned between the cutterhead and blower with their axis of rotation parallel to the cutterhead (Shinners et al. 2003). The rolls are serrated roller mill rolls operating at close spacing and differential speed. Roll clearance (roll gap) is typically from 1 to 5-mm, with a speed ratio from 5 to 25%, roll diameter from 150 to 300-mm, and the number of grooves between one and four per centimeter (Shinners et al. 2003).

Kernel processing increases machinery power requirements by 7 to 15% and slows the rate of harvest considerably (Schurig and Rodel, 1993; Roberge et al., 1998). Shinners et al. (2000) reported an increasing of harvester specific energy requirements by 11, 3, and 0% when harvesting WPCS at a 19-mm TLOC with processing at 1-, 3-, and 5-mm roll clearance, respectively, compared harvesting at 9.5-mm TLOC without processing. In some situations, producers or custom harvesters open the roll clearance to reduce kernel processing so they can save fuel and increase harvesting rate, however diminishing the kernel breakage. The TLOC settings also impacts on fuel requirements, for example increasing the TLOC saves fuel and increases the rate of harvest (Johnson et al., 2003). Kernel processing efficiency is influenced by different factors such as DM content of WPCS at harvest, TLOC, type of processor, and processor roll-gap clearance (Shinners et al., 2000; Ferraretto and Shaver, 2012a,b). Nowadays, there is a range of kernel processors types available on SPFH’s market. It is illustrated below the most important processors by each brand and recommendations of TLOC settings.
Class

Class has three options of kernel processors based according to TLOC setting: Multi Crop Cracker (MCC) Classic, MCC Max and MCC Shredlage®.

MCC Classic – It is a standard cracker system with saw tooth profile, suitable for short cut silage from 3.5 – 12-mm of TLOC.

MCC Max - Its rollers also feature a saw tooth profile, but split up into 30 segments each. It is the positioning and geometry of these segments which allows the chopped maize to be not only processed using friction, but also by cutting and shearing forces. It can cope with TLOCs from 7 to 20-mm.
MCC Shredlage® - It is cross-grooved crop-processing rolls set for 2- to 3-mm roll gap. The recommendations of TLOCs are based on DM of corn plant. 30% of DM – 30-mm, 35% of DM – 26-mm, and 40% of DM – 21-mm.


**Krone**

Krone also has 3 options of kernel processors:

The standard toothed rollers - The rollers on the standard corn conditioner measure 250-mm in diameter and have 105, 123, 144 or 166 teeth.
Salvati, G. G. S.; Nussio, L. G.

Hard chrome coating - The chrome plated corn conditioner measure 250-mm in diameter and are studded with 105, 123 or 144 teeth.

Disc rollers - With its V-shaped gaps, the disc conditioner has a 2.5 x larger friction surface than the standard conditioner. The disc rollers spin at the same speed, cutting the power requirement by 10%. The speed difference between the two rollers is 20% or, optionally, 30% or 40% for whole crop silage. The roller gap is adjusted in a range from 0.5-mm to 10-mm.

(kernelStar - The concept is based on a patented “bevel” disc design which allows for more intensive treatment of the kernels when compared to either the conventional cylindrical roll design or other disc designs. The design applies contoured intermeshing discs which provide an increased surface area

John Deere

KernelStar - The concept is based on a patented “bevel” disc design which allows for more intensive treatment of the kernels when compared to either the conventional cylindrical roll design or other disc designs. The design applies contoured intermeshing discs which provide an increased surface area

(http://www.krone-northamerica.com/english/products/literature/).
to enhance the crop processing. The kernel processor design features two rolls rotating in opposite directions and at different speeds. All models feature a 32% roll speed differential and the tooth profile of the bottom roll is reversed for more thorough processing. The KernelStar kernel processor now features up to fifty percent larger disc diameter and the same new adjustment mechanism and stronger springs as the roller processors.


**New Holland**

The standard crop processor has large (250-mm) rolls that are a full (750-mm) wide. The wider rolls mean more crop can fit through the small gap for maximum capacity. Both rolls have 99 saw teeth, and are driven at a 22% speed differential. There is a new processor, the heavy-duty processor, which rolls has 126 saw teeth and a 30% speed differential.
Horning crop processor – Fiber tech processors - this company sells kernel processors for all types of SPFHs and for some types of PTFHs (https://www.horningmfg.com/fiber-tech-roller.html). The latest product is fiber tech processor which shredders the fiber fraction.

There are other companies which are dealing in kernel processor sales market, Scherer inc. (http://www.schererininc.com/services/silage-processing/) and Kooima (https://kooima.com/shop/kernel-processor-roll-slow-110-tooth/).
Processors for Pull Type Forage Harvesters in Brazil

In Brazil for PTFHs, there are not too many options of kernel processors. The Nogueira brand includes in its new model of PTFH a screen which helps in grain breakage.


Dias Junior *et al.* (2015) evaluated the effect of this screen (S) at different TLOC settings on WPCS particle size and kernel damage. Corn (Dow 2B587 Hx) was harvested at half milk line maturity (36.4% DM, 52.1% NDF, 30.0% starch). Treatments were a factorial combination of TLOC (3, 4.5, 6, 8.5-mm) and S (with or without), and 50 m rows were harvested in triplicate. Visible kernels were quantified and classified in extreme (E), poor (P) or intact (I) breakage. Kernel *in situ* degradation in 12 h was 24.4% for E, 12.6% for P, and 11.5% for I, in 24 h 39.5%, 26.2%, and 23.6%. The S reduced visible kernels in forage (44.2 vs. 70.5 g/500 g forage,) and the proportion of P+I (23.2 vs. 41.0 g/500 g forage). The TLOC 3-mm without S (traditional in practice) had more visible kernels (56 g/500 g forage) than 8.5-mm with S (44 g/500 g forage). The reduction in visible kernels with smaller TLOC was larger when S was not used. Large TLOC with S resulted in forage with longer fiber and increased kernel damage than small TLOC without KP, which is nutritionally desirable. Recently, a new brand launched in the market a kernel processor for PTFH, however there is no data available yet.
There are other brands in PTFH’s market (JF, Menta and Casale) which the kernel processing is dependent of cutter knives.

**Methods to evaluate processing score and mean particle length**

**Processing score**

The corn silage processing score (CSPS) is a tool created to evaluate the adequacy of kernel processing (Ferreira and Mertens, 2005). Dried forage sample is sifted through several screens, and particles of corn which are generally smaller than one-fourth to one-third of a kernel pass through a screen with 4.75-mm openings. Therefore, it provides feedback on processing as “excellent” (>70% of sample starch passing through the screen), “adequate” (between 50 and 70% of sample starch passing through the screen), or “poor processed” (<50% of sample starch passing through the screen). Excellent processing score samples have a large portion of starch particles that are small and thus present a greater surface area for digestion.

The CSPS is also known by consultants and farmers as kernel processing score (KPS). Braman and Kurtz (2015) performed a study in 35 dairy farms to evaluate the effect of KPS of WPCS on the content of fecal starch of cows fed the corresponding WPCS. It was observed a negative relationship between percentage of fecal starch and KPS ($R^2 = 0.58$). In this study, the KPS ranged...
from 34% to 76%. A starch content of less than 2 to 3% has been suggested as goal in feces of lactating cows. Ferrareto and Shaver (2013) presented results from a sample survey of commercial testing labs over 2005 to 2012 showing a high percentage of corn silage samples categorized with poor processing (up to 42%) and a low percentage of samples categorized with excellent processing (only 7 to 17%) based on processing score measurements (Ferreira and Mertens, 2005). Recent data suggest that KPS increased over the time of ensiling (Ferrareto et al., 2015). The kernel processing is also affected by different whole-plant and kernel moisture content, TLOC, kernel processor, and roll gap (Shinners et al., 2000; Ferraretto et al., 2012 a,b). One limitation of the KPS is that a sample must be sent to a laboratory for analysis.

Savoie et al. (2004) created a method to separate kernel from stover fraction and that allows the visual evaluation of kernel processing during the harvesting time. This method is based on differences in buoyancy between the fractions (kernel and stover) and is performed in a bucket with water. The advantage is to adjust kernel processing roll during harvesting. Generally, corn particles should have >65 to 70% of kernels broken into pieces less than one-third to one-fourth of a kernel in size (Muck and Kung, 2017).

Recently, Dias Junior et al. (2016) purposed a new method to evaluate processing score. The study was based on (1) to evaluate particle size distribution and digestibility of kernels cut in varied particle sizes; (2) to propose a method to measure geometrical mean particle size (GMPS) in WPCS kernels; and (3) to evaluate the relationship between KPS and GMPS of the kernel fraction in WPCS. In the first part of the study, composite samples of unfermented, dried kernels from 110 corn hybrids commonly used for silage production were kept whole (WH) or manually cut in 2, 4, 8, 16, 32 or 64 pieces (2P, 4P, 8P, 16P, 32P, and 64P, respectively). Dry sieving to determine GMPS, surface area, and particle size distribution using 9 sieves with nominal square apertures of 9.50, 6.70, 4.75, 3.35, 2.36, 1.70, 1.18, and 0.59-mm and a pan, as well as ruminal in situ DM digestibilities were performed for each kernel particle number treatment. Incubation times were 0, 3, 6, 12, and 24 h. The ruminal in situ DM disappearance of unfermented kernels increased with the reduction in particle size of corn kernels. Kernels kept whole had the lowest ruminal DM disappearance for all time points with maximum DM disappearance of 6.9% at 24 h and the greatest disappearance was observed for 64P, followed by 32P and 16P (Figure 1).
Figure 1 - Relationship between ruminal in situ DM disappearance (% of DM) and geometric mean particle size (µm) in unfermented kernel. Prediction equation for 3 h: $y = 31.58 (\pm 4.53) - 0.007 x (\pm 0.01) - 4.170 x^2 (\pm 2.42)$; $n = 7$, RMSE = 2.10, $R^2 = 0.89$, $P = 0.01$. Prediction equation for 6 h: $y = 45.11 (\pm 2.42) - 0.007 x (\pm 0.01) - 2.428 x^2 (\pm 1.21)$; $n = 7$, RMSE = 1.05, $R^2 = 0.99$, $P = 0.001$. Prediction equation for 12 h: $y = 62.13 (\pm 6.74) - 0.004 x (\pm 0.01) - 5.909 x^2 (\pm 3.60)$; $n = 7$, RMSE = 3.12, $R^2 = 0.97$, $P = 0.001$. Prediction equation for 24 h: $y = 66.65 (\pm 4.47) + 0.001 x (\pm 0.01) - 0.001 x^2 (\pm 2.39)$; $n = 7$, RMSE = 2.07, $R^2 = 0.99$, $P = 0.001$.

In the second part of the study (Dias Junior et al., 2016), samples of WPCS ($n = 80$) from 3 studies representing varied TLOC settings and processor types and settings were also evaluated. Each WPCS sample was divided into 2 and then dried at 60°C for 48 h. The KPS was determined in duplicate on 1 of the samples, whereas on the other sample the kernel and stover fractions were separated using a hydrodynamic separation procedure (Sovie et al., 2004). After separation, the kernel fraction was re-dried at 60°C for 48 h in a forced-air oven and dry sieved to determine GMPS and surface area. Strong quadratic relationships between proportion of kernel fraction passing through the 4.75-mm screen and kernel fraction GMPS was observed ($R^2 = 0.69$). Linear relationships between KPS from WPCS ($n = 80$) and kernel fraction GMPS ($R^2 = 0.11$), and proportion passing through the 4.75-mm ($R^2 = 0.34$, Figure 2) screen were poor. Dias Junior et al. (2016) suggested that hydrodynamic separation and dry sieving of the kernel fraction may provide a better assessment of kernel breakage in WPCS than KPS.
The interface of forage harvester, kernel processing, and dairy cow performance

**Figure 2** - Relationship between kernel processing score (KPS: % of starch passing through 4.75 mm sieve) and proportion of hydrodynamically separated kernel-fraction passing through 4.75 mm sieve in whole-plant corn silage. Corn silage processing score prediction equation: $y = 37.55 \pm 4.54 + 0.39x \pm 0.06$; $n = 80$, RMSE = 4.96, $R^2 = 0.34$, $P < 0.01$.

**Mean particle length**

The Penn State Particle Size Separator (PSPS) is the common forage or TMR particle separation technique used in the dairy industry, primarily due to its ease of use on farm, but it requires manual manipulation of sieves that may induce human error (Maulfair and Heinrichs, 2012). The PSPS procedure uses 3 sieves (19, 8, and 1.18-mm) and a pan according to the method of Kononoff *et al.* (2003) and calculates the mean particle length (MPL) assuming logarithmically normally distribution as outlined by the ANSI (2001). Alternatively, the Wisconsin Oscillating Particle Separator (WI-OS) uses 5 sieves (26.9, 18, 8.98, 5.61, and 1.65-mm) and a pan (ANSI, 2001). It is the standard method accepted by agricultural engineers for determination of the particle size distribution and MPL of chopped forages (S424.1; ASABE,
Compared with PSPS, the WIOS is thought to have several advantages: it is mechanically operated, has a larger number of sieves, and has screens with greater surface area, which may limit human error (Maulfair and Heinrichs, 2012). However, the limited portability of the equipment due to the weight (>225 kg) and dimensions (102 × 64 × 145 cm, length × width × height) is a major disadvantage because it largely precludes use on farm (Maulfair and Heinrichs, 2012). Recently, Salvati et al. (2017a) reported high correlation (R²=0.62) between 2 different procedures to determine MPL in WPCS, suggesting that MPL can be measured adequately on farm with the PSPS.

In general, dairy farmers increase TLOC with the aim of increasing MPL of WPCS and thereby achieve greater physically effective fiber (peNDF). Salvati et al. (2017a) reported that verbal TLOC was unrelated to MPL of as-fed whole samples measured by either PSPS or WI-OS. A lot of factors can influence MPL in WPCS: kernel processing (Johnson et al., 1999; Mertens, 2005), processor roll-gap setting (Shinners et al., 2000), DM content (Shinners et al., 2000; Johnson et al., 2002), ratio of kernel to stover (Mertens, 2005), hybrid (Johnson et al., 2002), and knife sharpness and knife–to–shear bar clearance (Shinners, 2003). The TLOC is controlled by the peripheral speed of the feed rolls relative to the speed of the cutter head and the number of cutter head knives (Shinners, 2003), which also affects MPL.

Forage harvesters, mean particle length and kernel processing score on farms

Chopping forages to an adequate particle size is important to provide peNDF to the cows. For WPCS the TLOC are usually between 10 to 13-mm for unprocessed and about 19-mm for processed silage (~25-mm – for shredlage processed silage; Muck and Kung, 2017). The gap between the rollers (roll gap) is typically set between 1 and 3-mm, but the optimum setting will vary with conditions (e. g., kernel hardness in the field based on hybrids and maturity at harvest; Muck and Kung, 2017)

Salvati et al. (2015) performed a study around the Midwest of USA (Wisconsin, Minnessota and Illinois) which had the objectives to survey dairy farms about their corn silage harvest, processing and feeding practices, and collect corn silage samples for determination of processing score and MPL. Seventy-six corn silage samples were obtained from 69 dairy farms during farm visits from April to August 2014. Farms were located in Illinois (n = 1),
Minnesota (n = 15) and Wisconsin (n = 53). One sample was collected from each farm except for 7 farms that were feeding from two silos at the time of the visit. The samples were collected from the pile that had been shaved from the exposed face for feeding.

A summary of corn silage harvest practices used by the survey farms is in Table 1 - Most farms (61%) harvested corn silage using a Claas SPFH equipped with a Shredlage® processor. Most farmers reported a 22-26-mm TLOC (79%) and a 1.5-2.5-mm roll gap (82%).

Table 1 - Summary of silage harvest practices on the survey farms.

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>% of Surveys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-propelled forage harvester/processor</td>
<td></td>
</tr>
<tr>
<td>Claas with Shredlage® processor</td>
<td>61%</td>
</tr>
<tr>
<td>Loren-Cut® rolls</td>
<td>7%</td>
</tr>
<tr>
<td>Others</td>
<td>32%</td>
</tr>
<tr>
<td><strong>Theoretical length of cut</strong></td>
<td></td>
</tr>
<tr>
<td>&gt;26 mm</td>
<td>14%</td>
</tr>
<tr>
<td>26 mm</td>
<td>47%</td>
</tr>
<tr>
<td>22 mm</td>
<td>32%</td>
</tr>
<tr>
<td>≤19 mm</td>
<td>7%</td>
</tr>
<tr>
<td>Roll gap</td>
<td></td>
</tr>
<tr>
<td>&gt;2.5 mm</td>
<td>3%</td>
</tr>
<tr>
<td>2.5 mm</td>
<td>16%</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>48%</td>
</tr>
<tr>
<td>1.5 mm</td>
<td>18%</td>
</tr>
<tr>
<td>≤1.0 mm</td>
<td>15%</td>
</tr>
</tbody>
</table>

Adapted from Salvati et al. (2015).

The DM and starch contents were similar for the shredlage- and all-sample sets (Table 2). While average DM and starch contents were indicative of high-quality Midwest-USA corn silage, the range among farms was wide for both at 22%-units and 26%-units for DM and starch, respectively (Table 2). This likely reflects the challenges of weather conditions and harvest scheduling. Reducing variation in DM content is an area where corn silage quality could be improved (Salvati et al., 2015).
Table 2 - Survey descriptive statistics (mean, standard deviation, minimum and maximum) for whole-plant corn silage dry matter% (DM; as-fed basis) and starch% (DM basis), as-fed % retained on top (19-mm) and top 2 (8 and 19-mm) sieves of Penn State Particle Size Separator, mean particle length (MPL; mm) on as-fed samples with the WI Oscillating Screen Particle Separator, and kernel processing score on dried samples using a Ro-Tap shaker (% starch passing thru a 4.75-mm sieve).

<table>
<thead>
<tr>
<th>Sample(^1) (n)</th>
<th>Descriptive Statistics</th>
<th>DM%</th>
<th>Starch%</th>
<th>% PSPS Top Sieve</th>
<th>% PSPS Top 2 Sieves</th>
<th>WI-OS MPL (mm)</th>
<th>KPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (76)</td>
<td>Mean</td>
<td>34.2%</td>
<td>33.7%</td>
<td>17.9%</td>
<td>76.6%</td>
<td>11.8</td>
<td>66.2%</td>
</tr>
<tr>
<td></td>
<td>Stdev</td>
<td>3.8%</td>
<td>5.7%</td>
<td>8.1%</td>
<td>5.1%</td>
<td>1.4</td>
<td>5.7%</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>25.6%</td>
<td>17.1%</td>
<td>3.3%</td>
<td>65.1%</td>
<td>8.6</td>
<td>49.5%</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>47.1%</td>
<td>42.6%</td>
<td>43.7%</td>
<td>85.9%</td>
<td>14.8</td>
<td>82.7%</td>
</tr>
<tr>
<td>Loren-Cut (5)</td>
<td>Mean</td>
<td>33.6%</td>
<td>33.3%</td>
<td>14.7%</td>
<td>76.0%</td>
<td>10.9</td>
<td>66.0%</td>
</tr>
<tr>
<td></td>
<td>Stdev</td>
<td>4.1%</td>
<td>4.7%</td>
<td>6.5%</td>
<td>6.4%</td>
<td>1.9</td>
<td>9.0%</td>
</tr>
<tr>
<td>Conventional (6)</td>
<td>Mean</td>
<td>38.4%</td>
<td>36.9%</td>
<td>21.6%</td>
<td>82.4%</td>
<td>13.5</td>
<td>76.3%</td>
</tr>
<tr>
<td></td>
<td>Stdev</td>
<td>0.8%</td>
<td>3.4%</td>
<td>5.8%</td>
<td>2.9%</td>
<td>1.0</td>
<td>5.1%</td>
</tr>
<tr>
<td>JD-32% (5)</td>
<td>Mean</td>
<td>35.7%</td>
<td>36.6%</td>
<td>17.0%</td>
<td>82.7%</td>
<td>12.4</td>
<td>76.3%</td>
</tr>
<tr>
<td></td>
<td>Stdev</td>
<td>0.7%</td>
<td>0.1%</td>
<td>2.0%</td>
<td>2.6%</td>
<td>0.5</td>
<td>2.4%</td>
</tr>
<tr>
<td>Horning-32% (2)</td>
<td>Mean</td>
<td>35.4%</td>
<td>40.3%</td>
<td>8.2%</td>
<td>76.1%</td>
<td>10.1</td>
<td>72.1%</td>
</tr>
<tr>
<td></td>
<td>Stdev</td>
<td>2.7%</td>
<td>4.2%</td>
<td>5.6%</td>
<td>4.1%</td>
<td>0.7</td>
<td>4.0%</td>
</tr>
<tr>
<td>Intermeshing Disc (5)</td>
<td>Mean</td>
<td>35.0%</td>
<td>31.7%</td>
<td>20.7%</td>
<td>77.4%</td>
<td>12.1</td>
<td>64.7%</td>
</tr>
<tr>
<td></td>
<td>Stdev</td>
<td>4.8%</td>
<td>6.1%</td>
<td>10.8%</td>
<td>1.9%</td>
<td>1.3</td>
<td>2.3%</td>
</tr>
<tr>
<td>Unavailable (7)</td>
<td>Mean</td>
<td>27.0%</td>
<td>21.4%</td>
<td>7.1%</td>
<td>75.3%</td>
<td>10.4</td>
<td>60.9%</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>44.3%</td>
<td>38.8%</td>
<td>43.7%</td>
<td>81.1%</td>
<td>14.4</td>
<td>67.5%</td>
</tr>
</tbody>
</table>

\(^1\)Shredlage (Claas self-propelled forage harvester (SPFH), Shredlage® processor); Loren-Cut (varied SPFH, Loren-Cut® rolls); Conventional (varied SPFH, conventional processor); JD-32% (John Deere SPFH, conventional processor, 32% speed differential); Horning-32% (varied SPFH, Horning rolls, 32% speed differential); Intermeshing Disc (varied SPFH, varied disc processors); Unavailable (SPFH and processor type not indicated on survey). Adapted from Salvati et al. (2015).
Although the percentage retained on the top PSPS sieve was 7%-units greater for shredlage than the other defined (excludes the “unavailable” sample category) sample categories on average, the percentage retained on top 2 PSPS sieves and the WI-OS MPL were similar. This suggests not too much improvement in peNDF for the shredlage samples compared to the other samples collected in this survey. The average percentage retained on the top PSPS sieve for shredlage was substantially lower than that reported by Ferraretto and Shaver (2012b) from their feeding trial (20% versus 32%). It should be noted that the TLOC setting on SPFH was 30-mm for previous mentioned study, while the TLOC was usually 22-26-mm for the shredlage samples in this survey. The ranges for PSPS top sieve, PSPS top 2 sieves, and WI-OS MPL in the shredlage samples were 32%-units, 21%-units, 6-mm, respectively. Sample frequency distributions for PSPS top sieve are in Figures 3 (all samples) and 4 (shredlage samples).

![Figure 3 - Frequency distribution for % on the top screen of the PSPS on all samples.](image-url)
Figure 4 - Frequency distribution for % on the top screen of PSPS on shredlage samples.

All sample types fit in the adequately-processed category based on KPS (Ferreira and Mertens, 2005). The KPS was only 2%-units greater for shredlage than the other sample categories on average. This was achieved, however, coincident with the greatest percentage fibrous-particle retention on the top sieve of the PSPS for shredlage. The range for KPS in shredlage was 33%-units, and both the greatest and lowest KPS were observed within the shredlage samples. Sample frequency distributions for KPS are in Figures 5 (all samples) and 6 (shredlage samples).

Figure 5 - Frequency distribution for kernel processing score on all samples.
The survey included farmers that had been feeding SHRD in their herds for only 4 months to as long as 3 years. The following statistics were calculated from farmers using shredlage harvested with either a shredlage processor (n=46) or shredder roll kits (n=5) who had previously been using conventional processors. Processing rolls were relatively new with only 23% of respondents reporting usage on more than 30,000 as-fed tons. Most respondents reported either no change or being unsure about tons per hour throughput (63%) and roll wear (82%). Approximately 67% of the respondents reported no change or were unsure about fuel usage, whereas 30% reported an increase. Further research evaluating equipment-related aspects of corn shredlage is warranted. Although increased particle size of shredlage may cause concerns about packing density, only 4% of the respondents reported decreased packing density with shredlage. Furthermore, an increase in packing density was reported by a majority (51%) of the surveyed farmers.

A commercial lab in Brazil, ESALQlab, Department of Animal Science, ESALQ-USP shared some descriptive statistics of Brazilian WPCS in Table 3. In comparison with USA Midwest samples (Salvati et al. 2015) the means of DM (34.2 vs. 30.5%), starch (33.7 vs. 30.5%) and KPS (66.2 vs. 60.7%) of Brazilian WPCS samples were lower. These results indicated considerable opportunity to improve WPCS quality by reducing variation through better process control during harvest.
Table 3 - Descriptive statistics (mean, standard deviation, minimum and maximum) for Brazilian whole-plant corn silage dry matter % (DM; as-fed basis), NDF % (DM basis) starch % (DM basis), NDF digestibility %, and kernel processing score on dried samples using a Ro-Tap shaker (% starch passing thru a 4.75-mm sieve).

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>Stdev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM %</td>
<td>30.5%</td>
<td>5%</td>
<td>21%</td>
<td>43%</td>
</tr>
<tr>
<td>NDF %</td>
<td>45.3%</td>
<td>6%</td>
<td>35%</td>
<td>59%</td>
</tr>
<tr>
<td>NDFD %</td>
<td>49.2%</td>
<td>4%</td>
<td>39%</td>
<td>58%</td>
</tr>
<tr>
<td>Starch %</td>
<td>26.7%</td>
<td>6%</td>
<td>14.6%</td>
<td>38.5%</td>
</tr>
<tr>
<td>KPS %</td>
<td>60.7%</td>
<td>13%</td>
<td>30%</td>
<td>88%</td>
</tr>
</tbody>
</table>

Dairy cow performance

The pericarp of corn is poorly digested by rumen bacteria with minimal post ruminal digestion potential (Giuberti et al., 2014) and relatively resistant to rumen bacterial attachment (Huntington, 1997). Therefore, kernel damage during passage through the rollers coupled with enlarged surface area (Shinners et al., 2000), and thus increased bacterial attachment and digestion, may have led to greater starch digestibility (Huntington, 1997). Kernel processing at 1 to 2-mm roll gap has been shown to increase starch digestibility (Rojas-Bourrillon et al., 1987; Johnson et al., 1996; Bal et al., 2000) and decrease particle size of corn silage by 15 to 30% (Schurig and Rodel, 1993; Roberge et al., 1998). The reduced particle size does not provide adequate peNDF to maintain rumen health, so it is recommended that the TLOC be increased to 19-mm (Johnson et al., 2003). However, achieving greater peNDF with forage particles from greater TLOC may limit intake (Mertens, 1987) and increase diet sorting (Leonardi and Armentano et al., 2003).

Ferraretto and Shaver (2012a) performed a meta-analysis to study the effect of corn silage harvest practices on intake, digestion, and milk production by dairy cows. It was used data from 24 papers (27 trials and 106 treatments) published from January 2000 to June 2011. Categories for DM content at silo removal were ≤ 28% (VLDM), > 28 to 32% (LDM), >32 to 36% (MDM), > 36% to 40% (HDM) and >40% (VHDM) DM; for processing were 1 to 3 or 4 to 8-mm roll clearance or unprocessed; for TLOC were 4.8 – 6.4-mm, 9.3 – 11.1-mm, 12.7 – 15.9-mm, 19 to 19.5-mm, 25.4 to 28.6-mm, and ≥ 32-mm. The processing (1 to 3-mm) increased TTSD compared with 4 to 8-mm and unprocessed WPCS. Milk yield tended to be 1.8 kg/cow per day greater on average, for 1 to 3-mm and unprocessed than 4 to 8-mm. Ruminal starch digestibility was greater for WPCS harvested at 4.8 - 6.4 mm and 12.7 – 15.9-mm compared with 9.3 – 11.1-mm and ≥ 32-mm. Lower starch digestibility
when WPCS was harvested with longer particle size may be related to longer fiber fraction reducing kernel breakage during processing. Kernel processing with rollers set at 1 to 3-mm increased TTSD by 5.9 and 2.8 percentage units compared with 4 to 8-mm processed and unprocessed WPCS, respectively. Lower milk urea nitrogen (MUN) was observed when rollers were set at 1 to 3-mm compared with unprocessed WPCS.

Starch digestibility was increased when MDM and HDM WPCS were mechanically processed. Kernel vitreous endosperm proportion increases with increased DM content of WPCS (Philippeau and Michalet-Doreau, 1997). Thus, kernels in VLDM and LDM WPCS are likely more susceptible to breakage during harvest without kernel processing. A TLOC × kernel processing interaction was observed for TTSD. Kernel processing increased TTSD when TLOC was 9.3 to 28.6-mm. It is possible that a shorter TLOC allows for more kernel breakage by cutting knives (Johnson et al., 1999), which minimizes the effect of processing on TTSD. Furthermore, at longer TLOC the stover portion of WPCS may inhibit kernel breakage during passage through the rollers, thereby reducing the effect of processing on TTSD. Milk fat content was greater for unprocessed WPCS than for WPCS processed at 1 to 3-mm (3.55 vs. 3.44%). Ruminal NDF digestibility was unaffected by kernel processing.

Salvati et al. (2017b) studied effect of kernel processing on Brazilian vitreous endosperm corn hybrid and increment of particle size in WPCS on dairy cow performance and starch digestibility. The treatments were performed during the harvesting. 1) Pull type forage harvester (without kernel processor, JF AT 1600) set for a 6-mm TLOC - PT6, 2) Self-propel forage harvester (New Holland, FR 9050) set for a 6-mm TLOC - SP6, 3) Self-propel forage harvester set for a 12-mm TLOC - SP12, and 4) Self-propel forage harvester set for a 18-mm TLOC - SP18. The processing score of the WPCS were: 32.9% - PT6, 54.0% - SP6, 45.7% - SP12, and 37.6% - SP18. Twenty four (139 ± 63 DIM) Holstein cows were blocked and assigned to six 4 × 4 Latin squares, with 24-d periods (18 d of adaptation). Diets were formulated to contain 48.5% of WPCS, 9.5 % of soybean meal, 6.9% of soybean meal nonenz. brown, 15.1% of dry ground corn, 15.5% of citrus pulp, 1.7% of minerals and vitamins mix, 1.8% of calcium soap of palm fatty acids, and 1% of urea. The nutrient composition of the diets was: 16.5 % CP, 31.7% NDF and 26.1 % Starch (approximately 55.5% of starch was from WPCS). It was used three orthogonal contrasts to compare treatments: 1) PT6 vs. SP6 (effect of kernel processing), 2) SP6 vs. SP12 (effect of particle size), and 3) SP12 vs. SP18 (effect of particle size).

Cows fed SP6 silage increased milk yield by 1.2 kg/d without affect dry matter intake when compared with PT6 (Table 4), as a consequence the feed
efficiency (milk/DMI) improved. There was no difference between SP6 and SP12, however, when it was compared SP12 with SP18 a numerical milk production reduction (0.8 kg) was observed (P = 0.11). Greater milk production was probably induced by an increase in starch digestibility as indicated by a reduction in fecal starch in SP6 treatment. Moreover, plasma glucose concentration increased by 4.1 mg/dL in SP6. Cooke and Bernard (2005) reported greater plasma glucose in dairy cows fed with processed WPCS. MUN was lower for cows fed processed silage (SP6). Lower MUN may be related to increased ruminal starch digestibility and thus improved ruminal nitrogen coupling (NRC, 2001). SP12 had less milk protein content than SP6. No more difference was observed in milk solids composition. The SP-18 tended to increase fecal starch and to reduce plasma glucose. Higher fecal starch was observed when WPCS was harvested with longer particle size (SP18) may be related to the longer fiber fraction reducing kernel breakage during processing of WPCS through rollers at harvest as described by Ferraretto et al. (2012a). Several factors, including endosperm properties (Correa et al., 2002), maturity (Johnson et al., 2002), and degree of processing (Bal et al., 2000) of WPCS alter the fragmentation of kernels and thereby the digestibility of starch (Cooke and Bernard, 2005).

Table 4 - Performance, plasma glucose and fecal starch of dairy cows fed with PT6, SP6, SP12 and SP18 WPCS.

<table>
<thead>
<tr>
<th>Item</th>
<th>PT6</th>
<th>SP6</th>
<th>SP12</th>
<th>SP18</th>
<th>SEM</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>C₁</td>
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<td>C₂</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>C₃</td>
</tr>
<tr>
<td>DMI (kg/d)</td>
<td>19.9</td>
<td>19.3</td>
<td>19.4</td>
<td>19.5</td>
<td>0.67</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Milk (kg/kg)</td>
<td>28.2</td>
<td>29.4</td>
<td>29.4</td>
<td>28.6</td>
<td>0.33</td>
<td>0.061</td>
</tr>
<tr>
<td>Milk/DMI (%)</td>
<td>1.42</td>
<td>1.52</td>
<td>1.49</td>
<td>1.47</td>
<td>0.061</td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.54</td>
<td>3.40</td>
<td>3.42</td>
<td>3.38</td>
<td>0.103</td>
<td>0.19</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.31</td>
<td>3.31</td>
<td>3.23</td>
<td>3.27</td>
<td>0.088</td>
<td>0.95</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>4.62</td>
<td>4.65</td>
<td>4.63</td>
<td>4.61</td>
<td>0.038</td>
<td>0.17</td>
</tr>
<tr>
<td>Solids (%)</td>
<td>11.47</td>
<td>11.35</td>
<td>11.27</td>
<td>11.22</td>
<td>0.125</td>
<td></td>
</tr>
<tr>
<td>MUN (mg/dL)</td>
<td>11.3</td>
<td>10.2</td>
<td>10.7</td>
<td>10.2</td>
<td>0.90</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Glucose (%)</td>
<td>61.6</td>
<td>64.7</td>
<td>64.3</td>
<td>61.9</td>
<td>2.62</td>
<td>0.03</td>
</tr>
<tr>
<td>Fecal starch (%)</td>
<td>5.8</td>
<td>4.4</td>
<td>4.7</td>
<td>5.7</td>
<td>0.48</td>
<td>0.061</td>
</tr>
</tbody>
</table>

¹Contrasts: C₁ - PT6 vs. SP6 (effect of kernel processing), C₂ - SP6 vs. SP12 (effect of particle size)
The interface of forage harvester, kernel processing, and dairy cow performance

Lower TLOC decreases the contents of peNDF, as well leads to an increased degradation of starch, might be useful in enhancing feed intake and energy output but negatively affects rumen health and functioning (Nasrollahi et al., 2015; Nasrollahi et al., 2016). However, long TLOC may increase sorting and decreases feed intake (Leonardi and Armentano, 2003). It is well known that dairy cows require a minimum amount of fiber that is of adequate particle size to stimulate chewing and to obtain a healthy ruminal environment (Beauchemin and Yang, 2005). In regard, the concept of peNDF has been widely accepted as an appropriate measure to take the physical (i.e., particle size) as well as chemical properties of the fiber (i.e., the NDF content) into account (Zebeli et al., 2008). The peNDF can be determined as peNDF_{>8} (proportion of particles > 8-mm multiplied by the NDF content) and is necessary the use of PSPS. The recommendation of peNDF_{>8} in dairy rations ranges from 16 to 20% of DM, depending of starch content and DMI level (Zebeli et al., 2012).

Nasrollahi et al. (2015) conducted a meta-analysis of 46 studies that studied the effect of forage MPL on performance and nutrient digestibility in dairy cows. It was observed that decreasing in MPL enhanced DMI (0.527 kg/d) and NDF intake (0.166 kg/d). This effect was observed pronounced in diets containing high levels of forage (>50% of DM). The improvement in DMI due to a reduction in MPL occurred for diets containing silage but not hay. Summarizing studies conducted mainly WPCS as forage source, revealed that when TLOC was reduced from on average 23.3 ± 8.22-mm to 10.2 ± 6.78-mm, the DMI was increased by on average 0.6 kg with a range from −1.1 kg to +2.3 kg (Zebeli and Humer, 2017). The meta-analysis revealed an increase in milk yield of 0.5 kg/d in cows fed finer particles, higher protein content and a reduction 0.06% in fat content (Nasrollahi et al., 2015). The effect of MPL in dairy cows performance apparently depends of proportion of forage in the diet (Yang and Beauchemin, 2009), forage source (Krause and Combs 2003), forage preservation method (i.e. hay vs. silage; Calberry et al., 2003).

A novel method of harvesting WPCS appeared recently, Shredlage (SHRD), increase kernel processing and peNDF. It is potential tool for dairy producers and their nutritionists desiring to feed higher WPCS diets without compromising kernel breakage and energy availability for WPCS chopped at a greater TLOC. The SHRD is harvested with a commercially available SPFH fitted with after-market cross-grooved crop-processing rolls set for 2- to 3-mm roll gap and greater roll speed differential than has typically been used (32% versus 21%). Also, the developer of this processor recommends that the SPFH size), and C_{3} - SP12 vs. SP18 (effect of particle size).
be set for a longer TLOC (26 to 30-mm) than has typically been used in the past (19-mm TLOC; Ferraretto and Shaver et al. 2012b)

Two feeding trials were performed in University of Wisconsin-Madison. The first one, Ferraretto and Shaver (2012b) compared conventionally processed corn silage (KP) and SHRD in a dual-purpose hybrid. The KP was harvested using conventional rolls (roll gap of 3-mm) and set at a 19-mm TLOC. The SHRD was harvested using novel-cross grooving rolls (roll gap of 2.5-mm) and set to 30-mm. One hundred twelve cows stratified by DIM, milk yield, breed, and parity were randomly assigned to 14 pens with 8 cows. Pens were randomly assigned to 2 treatments TMR in a completely randomized design. A 2-wk covariate period with cows fed a 50:50 mixture of treatment diets was followed by an 8-wk treatment period with cows fed their assigned treatment diet. The TMR contained (DM basis) KP or SHRD (50%), alfalfa silage (10%), and concentrate mixture (40%). The processing score of WPCS were 75% - SHRD and 60.3% - KP. Cows fed SHRD tended to consume 0.7 kg/d more DM. There was only a numerically improvement on milk yield by 0.8 kg. Milk composition was similar between treatments. The 3.5% fat corrected milk (3.5% FCM) yield tended to be 1.0 kg/d greater for cows fed SHRD. A treatment × week interaction was detected for 3.5% FCM yield; as during wk 2, a tendency was observed for SHRD to be greater during wk 4 and 6 and greater for SHRD at wk 8. Ruminal in situ digestibility of starch was greater for SHRD than for KP. Feeding SHRD tended to increase DMI and 3.5% FCM yield. The rumination activity and sorting behavior were not evaluated in this trial.

In the second feeding trial, (Vanderwerff et al., 2015) the objective was to determine the effect of feeding TMR containing brown midrib (BMR) corn SHRD compared with BMR conventionally processed corn silage (KP) or KP plus chopped alfalfa hay (KPH) on intake, lactation performance, and total-tract nutrient digestibility in dairy cows. The primary objective of our study was to determine the effect of feeding BMR SHRD compared BMR KP on lactation performance and starch digestibility in dairy cattle fed TMR. The hypothesis was that to improve fiber effectiveness may be especially advantageous when feeding BMR corn hybrids, which have reduced lignin content. A secondary objective was to determine the effect of feeding BMR SHRD compared with BMR KP with added chopped alfalfa hay (KPH) in TMR to evaluate SHRD as a source of peNDF.

The KP was harvested using conventional rolls (2-mm gap) and the SPFH set at 19 mm of TLOC, whereas SHRD was harvested using novel cross grooved rolls (roll gap of 2-mm ) and the SPFH set at 26-mm of TLOC. Holstein cows
(n = 120; 81 ±8 d in milk at trial initiation), stratified by parity, days in milk, and milk yield, were randomly assigned to 15 pens of 8 cows each. Pens were randomly assigned to 1 of 3 treatment diets, SHRD, KP, or KPH, in a completely randomized design using a 2-wk covariate period with cows fed a common diet followed by a 14-wk treatment period with cows fed their assigned treatment diet. The TMR contained (DM basis) KP or SHRD forages (45%), alfalfa silage (10%), and a concentrate mixture (45%). The processing score of WPCS were 72.4% - SHRD and 67.6% - KP. Hay replaced 10% of KP silage in the KPH treatment TMR (dry matter basis). Milk, protein, and lactose yields were 3.4, 0.08, and 0.16 kg/d greater, respectively, for cows fed KP and SHRD than KPH. A week by treatment interaction was detected for milk yield, such that cows fed SHRD produced or tended to produce 1.5 kg/d per cow more milk, on average, than cows fed KP during 6 of the 14 treatment weeks. Component-corrected milk yields were similar among treatments. Cows fed KPH had greater milk fat concentration than cows fed KP and SHRD (3.67 vs. 3.30% on average). Consumption of dry matter, rumination activity, and sorting behavior were similar among treatments. Ruminal in situ starch digestibility was greater for SHRD than KP forages, and total-tract dietary starch digestibility was greater for SHRD than KP. Milk yield (51.3 vs. 50.1 kg/d) and starch digestibility (99.1 vs. 98.6%) were greater for SHRD than KP. Lack of improvement in milk fat content and rumination activity for SHRD compared with KP and reduced milk fat content for SHRD compared with KPH, however, suggest no improvement in peNDF from the longer TLOC used with SHRD in a BMR hybrid.

Summary

There are different types of kernel processors available to SPFH in the Brazilian market; however, little options are available to PTFH. The CSPS or KPS is the most common method used to evaluate kernel processing, but new methods are being studied. The MPL can be measured adequately on farm by PSPS. In the Midwest region of the USA, 93% of farmers are using long TLOCs (>26-mm), 81% are using roll gab bellow 2-mm, and 61% are using the Shredlage® processor. A small number of studies have been published comparing the effectiveness of kernel processing among processors and its effect on vitreous corn hybrids in dairy cow performance. In a feed trial conducted in Brazil with a vitreous corn hybrid, dairy cows fed kernel processed WPCS (at 6-mm and 12-mm of TLOC) increased milk yield by 1.2 kg, possibly due
to improvement in starch digestibility. Nevertheless, at 18-mm TLOC, there was numerical reduction in milk yield followed by a tendency to increase fecal starch and to reduce plasma glucose. These results may be related to longer fiber fractions, which reduce kernel breakage during processing of WPCS through rollers at harvest. The trials using the Shredlage® processor reported improvement in dairy cow performance and starch digestibility even at long TLOCs (>26-mm). More studies are needed to fully understand the effect of specific kernel processors, TLOC, and roll gap settings on starch digestibility which could potentially improve dairy cow performance specially in vitreous corn hybrid WPCS.

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The interface of forage harvester, kernel processing, and dairy cow performance

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Introduction and early challenges to AMS grasslands farming

The development of robotic milking commonly known as AMS (Automatic Milking Systems) begun during the eighties. In those days, many of the tasks involved in milking cows already had been successfully automated. Nevertheless, cupping cows remained to be a manual task that meant that people had to be around cows during the entire milking process.

Therefore, robotic milking came as a response to the need to free up labour mainly driven by the European family farm.

In the early days of AMS, the main challenge was fundamentally technical and mechanical as at the time technology was not accurate enough to allow for the accurate task of attaching cups to a cow. These technical issues were reported and presented in the early symposiums and seminars held during the early nineties (Figures 1 & 2).

Figure 1 - Early robotic solution. Silsoe Institute 1987.
As technology developed and was made available, these early problems were gradually resolved. By the turn of the century, there were several farms operating with robots primarily in Europe.

![Early patent by DeLaval 1982.](image)

The next challenge AMS faced was to add value to the daily farming operation and this was done through the addition of new sensors that had become available during the following decade. Sensors such as, individual (quarter) milk metering, conductivity and cell counting were incorporated and this made robotics the most important source of information for the farmer.

Still at this stage, robots were mainly operating within the well-established confined dairy system predominant in Europe and the Northern Hemisphere. During this decade, AMS were running in typically 1 or 2 box operations. At this time, some larger operations decided to go into robotics and they were successful, thus generating interest in the larger herd segments.

What was missing, was the grasslands operations that are the preferred dairy system mainly in the Southern Hemisphere. These systems base their operation on the usage of pasture, harvested directly by the cow, as the main feed source. The herd sizes in grasslands operations also vary and these might go from a few cows up to a couple of thousand animals all under a grazing grass utilisation system.

The main challenge for these systems was the distances that cows must travel in order to be milked. With the understanding that the system had to operate under a voluntary basis, it was clear from the beginning that there was
a need to get a cow flow, to the robots that had to be evenly spread during the 24 hour period.

Several researchers worked, mainly in New Zealand and Australia, on how to get cow traffic going in these systems. The main conclusion of this research was that the main driver for voluntary cow traffic was feed allocation. In simple terms this meant that as cows started to run out of grass they would learn that by moving and passing through selection gates, they would be rewarded either by being sent through to be milked (and some supplement feed given in the AMS) or to fresh paddocks.

Once this key cow behaviour aspect, was identified and properly understood, it was a farmer’s decision on how he should operate the system to allow the cows to traffic through the system. This grasslands robotic system started to operate in the later part of the last decade, and on a larger scale since 2010.

Today it is very safe to state that AMS is a valid alternative to all dairy farming systems from all grass operations all the way into highly intensive and total confinement operations. Also these systems can cope with almost all herd sizes (Figure 3).
Key drivers for AMS, the global trends

Currently there are around 40,000 robots operating around the world. As stated, these are mainly in small family farms in Europe with one or two robots. A growing number of larger operations are in operation and the trend is to see an increased number of larger operations incorporating AMS.

The key global drivers to incorporate AMS are:

- Labour management and availability — in developed countries, this has become one of the major issues farmers are facing. The lack of interest and availability of labour is a reality with strong trends to be seen on migrations of people from other countries to do the milking. Good examples are Mexican people in the U.S. and people from the Philippines into New Zealand. In developing countries the lack of labour is mainly related to the skill and knowledge level needed to run successful dairy operations.

- The need to increase production — as dairy business is a (milk) volume game, there is the constant need to increase production with
no major increases in inputs to achieve that growth. Thus, increasing productivity from a cow, system and labour standpoint have become increasingly important.

- The ability to expand in a profitable way ==> related to the production growth, the strong global trend towards larger herd sizes in order to maximise productivity of land, infrastructure and labour.
- Lower the cost of milk harvesting ==> lower the cost per litre harvested per unit labour
- Flexibility and choice of lifestyle ==> coming strongly, as one of the main drivers, into the family operated farms
- Succession planning ==> making dairy farming attractive to the younger generations who are proficient in the use of electronic equipment and computers. This on an attempt to avoid exodus from farms into cities.

These drivers are listed in no particular order as they will vary in importance depending on the different markets

The grassland dairy farming challenge to the AMS
Grassland farming is of key importance in the Southern Hemisphere. The New Zealand, from grass to milk philosophy, has been adopted and adapted to accommodate farming in different regions and countries

The New Zealand dairy industry imposes its own challenges to the adoption of AMS. These can be summarised as follows:

- Largest exporting dairy country in the world
- Decrease in herd numbers
- Increase in cow numbers
- Increase in average herd size
- Nationwide distribution of dairy herds
- Amongst the lower milk prices paid to farmers
- Seasonal calving
- Well defined dairy production systems

**Key elements to consider on a grasslands voluntary milking system**

- Cows will traffic on a voluntary way mainly driven by hunger as the grass allocation on a specific area starts to run short
It is vital to understand that, in order to keep cows moving, the right amount of grass must be made available (the cow must always, during the day, have an incentive to move) and as a consequence of this the three way grazing system was developed and has become the preferred option (Figure 4.)

The basis of the three way grazing system is to divide the farm ideally in three similar grazing areas. These areas are allocated to the cows during the 24 hour day. In this way, typically a farm will have night, morning and evening paddocks that cows will have access during the 24 hour time frame.

An excess of grass allocated will make cows comfortable to stay in the paddock as there is enough grass available. This will slow down cow traffic as there is no incentive to leave.

On the other side, a shortage of grass allocated will have two negative effects, on one hand a drop in milk production and on the other it will stimulate many cows to move as the grass runs out. The later will generate congestion at the selection gates and the milking robots. Always remember that a milking robot is only one milking point!

Grass management and allocation is particularly important on a grazing voluntary milking system. The use of a plate meter is important to be able to allocate the correct amount of grass to the cows, avoiding excess or shortages, as previously explained.
Properly designed lanes must be available to facilitate cow traffic to and from the milking centre and on to all the grazing areas. These lanes do not necessarily need to be the same as used in conventional farms as, if properly run, a voluntary milking grazing system will consider smaller numbers of cows moving at a time. No longer is the entire herd moving.

There will always be a certain number of cows that are slow or reluctant to move and therefore a percentage of fetching will need to be considered in these systems. Consider fetching as part of the daily operation but adjustments need to be made if the number of fetched cows goes beyond an acceptable number as this might mean that grass allocation is not good enough or milking permissions need to be checked.

These slow to move cows will typically be in late lactation and, therefore, are less stimulated to move, as their production drops. Nevertheless, these cows play an important role in maintaining the grass residuals to the required height to ensure proper grass regrowth.

As mentioned, fetching cows must be considered as part of the daily routine and not taken as a failure of the system. This must be done in conjunction with other tasks that need human intervention (i.e. evaluating amount of grass in the paddocks, reviewing the grass residuals, moving the electric fence for the next break, etc). Fetching does not mean to bring cows to the selection area but to simply make sure any remaining cows are put onto the race for her to start moving towards the selection area.

The three way grazing system demands accurate grass management from the farmer’s side. Daily pasture evaluations in order to have a clear understanding of grass availability is of critical importance in order to achieve the voluntary cow traffic. Grass availability and quality evaluations must be done on a daily basis to adjust the area allocated to the cows.

Managing calving spread and stocking rate is critical in order to manage feed availability, and the periods of shortage as well as excess. All this is a dynamic process that needs to be incorporated into the daily routine on the farm. (Figure 5).
A key element that farmers need to understand is related to the milking permissions.

As an AMS box system milking installation is basically a limited number of milking points, and based on the fact that cows vary in milk production and lactation stage, the correct management dictates for the farmer or farm manager to allocate milking permissions to the cows based on these elements.

As a general rule of thumb, in early lactation, and as cows produce more milk, these animals should be granted frequent milking permissions to stimulate them to come often and deliver reasonable amount of milk. As lactation progresses, it does make sense to increase the time between visits to the robots in order to avoid having cows using the robots with low milk yields and using milking capacity, that would be more efficiently used by higher yielding cows.

The milking permissions can be organised based on lactation stage, production or a mix of both, whichever the farmer decides to use.
The milking permission approval or rejection can be done in the selection gate, prior to the milking robot or in the milking robot itself.

**Changes in the farming system**

An AMS farm must consider three key elements:

1. The daily work routine no longer revolves around milking time ==> the fact that no labour involvement is needed during milking time, makes this labour available to perform other tasks that are important and in many cases are either done after hours or not done at all
2. The milking machine becomes the main source of data collection and herd control ==> the presence of newly developed sensor technology delivers to the farmer an unprecedented amount of information allowing him to take action and manage his farm
3. The herd is less of a key element in the daily operation, as individual cow information becomes available ==> the individual cow information allows the farmer to manage by exception rather than having to spend long hour to identify problematic cows in a herd (Figure 6).
Figure 6 - Difference between Conventional and Automatic Milking Systems. The herd is less important as individual cow information becomes available.
Other important aspects that need attention from a farmers (and advisors) perspective are:

- Genetics ==> some of the traits to focus, might slightly vary in importance, when compared to conventional milking

- The AMS (robotic) option ==> today there are two main robotic options in the market. The more traditional box system, where cows enter individually into the box to be milked and, the robotic rotary where cows get on to a rotating platform to be milked. These two systems offer different features and benefits to the operation. These might accommodate in a different way to the farmers farming system and they need to be evaluated by the farmer before deciding on one. (Figure 7).

![Dairy Production System](image)

**Figure 7** - Two robotic alternatives. Box system and Rotary system.

**How should an AMS system operate?**

We believe there should be four critical aspects that such a system should take into consideration to allow for a successful grasslands operation (Figure 8):
1. The robots should be integrated into a system and work within it. The robot is only one part of the system (an important part though) but the rest of the system is also critical to the success of the operation. This is valid in all farming systems but particularly critical on grasslands systems.

2. The system must allow for on farm analysis. Farmers must obtain valuable and accurate information to make informed management decisions.

3. The system must operate incorporated into a strong and user friendly herd management system. This will allow the farmer to efficiently manage the daily tasks providing him with information of cows, herd, system, etc. so he can manage the exceptions and drive productivity.

4. Upgradeability. The technology is evolving very rapidly and these systems must be flexible enough to be able to incorporate these new technologies as they become available.

**Operational parameters**

The performance parameters of an AMS operation are different to the KPI’s that are considered in conventional systems.

Milkings per cow, cow milkings per station, litres of milk harvested per station, etc. are all KPI’s that are very much looked into in AMS systems. (Figure 9).
Some current AMS operators openly state that it is “More difficult to change the farmer than the cow”. Therefore it is vital to a successful AMS implementation that the farmer gets exposure to operating systems and demands training prior to start up and after start up support from the suppliers in order to realise their expectations.

**Evolution and going forward**

There is little doubt that AMS is the greatest technological shift that has happened in dairy farming in the latter 30 years.

This has not only meant a significant change to the cow, going into voluntary milking, but mainly to the farmer to understand and accept that his/her role (and that of his/her employees) has significantly changed from the moment they are no longer needed during milking time. Now they can do farm management tasks and operational activities during that time frame.

In essence a grassland AMS system is managed by the cows and accepting and managing the new farming system that is imposed by the voluntary and cow driven pace is key to master a successful grassland AMS operation.

What robotics is giving to farmers and workers, is time to do or improve what they could not do in the past as their time was limited to available time outside milking time.
This technology is allowing farmers to transition from operational chores to management and further on into strategy and growth planning (Figure 10).

![Figure 10 - Moving from operational to management and thinking strategic farming](image)

In the foreseeable future, dairy farmers will be facing other significant challenges amongst them.

- Animal management based in a rational use of antibiotics, considering a drastic reduction in their usage.
- More work to be done in the usage of Nitrogen, not only at plant and soil level but also through its dilution in food and its manipulation in the rumen environment.
- Successful dairy systems will focus on increased dairy cow longevity and productivity through proper animal welfare.

Of these challenges, AMS dairy farmers are well positioned to achieve significant progress on them, due to the animal friendliness of the system, the outstanding cow monitoring and the increase in productivity of the system and the operators (Figure 11).
Figure 11 - Farmers discussing AMS grassland farming in a robotic dairy farm in Tasmania, Australia.
SILAGEM DE GRÃOS DE MILHO E SORGO PARA VACAS LEITEIRAS

Pereira, M. N.

Introdução

O amido em grãos de cereais, como milho e sorgo, é importante para maximizar a síntese de proteína microbiana no rúmen (Hall e Herejk, 2001) e contribui substancialmente para a energia necessária para lactação em gado leiteiro. A ensilagem é um método eficaz e relativamente barato de armazenamento de grãos na fazenda. Comparado com o grão maduro moído, a ensilagem dos grãos concentra a operação de moagem e reduz mão-de-obra na fazenda, reduz o investimento em equipamentos e instalações para armazenagem de grãos, elimina custos de armazenamento, secagem e transporte para silos comerciais e pode reduzir as perdas durante a estocagem e processamento. A ensilagem de grãos imaturos também permite a colheita mais precoce da lavoura, reduzindo perdas no campo e permitindo a semeadura mais rápida de culturas sucessivas.

Tipos de silagens de grãos

Silagens de milho úmido (SMU) ou de grãos maduros reidratados de milho (SMR) ou sorgo (SSR) têm sido utilizadas para o gado leiteiro. Outros grãos, como trigo e aveia, também podem ser armazenados como silagem adotando os mesmos processos. Na SMU, grãos de milho colhidos em torno do estágio de maturidade de linha negra (25 a 40 % de umidade) são grosseiramente moídos ou esmagados antes da ensilagem. A SMU pode ser confeccionada apenas com os grãos, com os grãos e o sabugo (Earlage), ou com grãos, sabugo e palha (Snaplage). A snaplage tem teor de fibra mais alto que a silagem de grãos puros e a earlage, o que reduz o conteúdo de energia no alimento. Dietas contendo snaplage normalmente limitam o uso de subprodutos fibrosos na dieta, como polpa cítrica, casca de soja, resíduo de cervejaria e farelos de glúten de milho ou trigo, dentre outros. Na earlage tem sido assumido que a fibra oriunda de sabugos ensilados no estágio de linha negra do grão são bem digeridos relativamente ao amido (San Emetério et al., 2000).
As SMR e SSR são o produto de adição homogênea de água a grãos maduros moidos para obter mais do que 30 % de umidade para ensilagem (Andrade Filho et al., 2010b; Pereira et al., 2013). Comparado com o armazenamento tradicional como SMU, a SMR tem a vantagem de permitir uma janela mais ampla de colheita da cultura ou a compra estratégica de grão seco maduro. Desde que a concentração de umidade no grão maduro é geralmente inferior a 15 %, moagem fina pode ser adotada, permitindo que grãos de sorgo sejam completamente danificados para ensilagem como SSR. Moagem grosseira de grãos úmidos de sorgo resulta em alta proporção de grãos inteiros na silagem e aumento na perda fecal de amido. A SSR é a opção mais indicada para armazenamento de sorgo por ensilagem na fazenda.

Dados de degradação ruminal in situ sugerem que SSR é no mínimo tão digestível no rúmen quanto SMR (Fernandes et al., 2017). Estes autores reidrataram grãos maduros de sorgo e milho para obter concentração de umidade de 35 % para ensilagem em mini-silos de laboratório por 30 e 180 dias. Ambos os grãos foram moidos com a mesma peneira com diâmetro de crivo de 3 mm em um moinho de martelo. O tamanho geométrico médio do sorgo foi menor que o do milho (129 vs 211 µm) e o conteúdo de prolamin após a ensilagem foi similar (9,5 % do amido). A degradação efetiva no rúmen (DEF) foi estimada com um modelo 2-pools (frações A e B), usando a matéria seca (MS) residual em incubações no rúmen por 3, 6, 12, 18 e 48 h e uma taxa fracional de passagem (kp) de 6 %/h [DEF = A + B × kd / (kd + kp)]. A silagem de SSR teve uma maior fração A instantaneamente degradável (39,8 vs 32,5 % da MS) e menor taxa fracional de degradação da fração B (kd. 3,14 vs 3,33 %/h) do que SMR. A DEF foi 60,3 % da MS para SSR e 56,5 % da MS para SMR. A ensilagem de sorgo é uma opção para reduzir o custo de grãos na dieta em relação ao milho, sem penalizar a digestibilidade do amido no rúmen.

**Digestão do amido e formulação de dietas**

A ensilagem de grãos pode afetar a proporção do amido dietético digerido no rúmen ou nos intestinos (Oba e Allen, 2003b). Durante a ensilagem, proteínas complexadas aos grânulos de amido no endosperma dos grãos (Prolaminas. Zeína no milho e Kafirina no sorgo) são degradadas por proteases microbianas e da planta (Heron et al., 1986; Hoffman et al., 2011), o que aumenta a digestibilidade ruminal e intestinal do amido (Knowlton et al., 1998). Com base em dados de 6131 amostras de SMU oriundas de um laboratório comercial,
e assumindo que o mês de envio da amostra para o laboratório representava a duração da ensilagem, Ferraretto et al. (2014) observaram que o ganho na digestibilidade do amido in vitro foi proporcional à duração do armazenamento e até 10 meses pode ser necessário para alcançar a máxima digestibilidade do amido. O efeito da ensilagem sobre a digestibilidade do amido pode ser exacerbado em áreas onde a indústria leiteira utiliza sorgo e híbridos de milho de endosperma duro (flint) que contêm maior proporção de endosperma vítreo do que milho farináceo (Andrade Filho et al., 2010a) ou quando moagem grosseira ou esmagamento é adotado como uma estratégia para aumentar a taxa de processamento do grão. A SMR demonstrou ser tão eficaz quanto SMU na redução do teor de prolamina do milho (Fernandes, 2014).

Estimativas in vivo da digestibilidade ruminal do amido obtidas com vacas em lactação canuladas sugerem que a proporção do amido digerido no rúmen ou nos intestinos pode ter grande variação em vacas em lactação. A digestibilidade ruminal do amido foi 61,5% da ingestão em uma dieta contendo silagem de milho farináceo e 29,0% em uma dieta com milho duro (Taylor e Allen, 2005). Rémond et al. (2004) observaram que a variação na digestibilidade ruminal do amido em vacas alimentadas com milho maduro diferindo no tamanho de partícula foi de 35,5 a 69,8% do ingerido. Oba e Allen (2003b) observaram que a digestibilidade ruminal do amido variou de 45,9 a 71,1% do ingerido quando dietas diferiram no teor de milho maduro finamente moído ou de SMU. Callison et al. (2001) detectaram uma variação na digestibilidade ruminal do amido de 35,5 a 70,1% da ingestão em resposta a milho moído diferindo no tamanho de partícula. Knowlton et al. (1998) observaram digestibilidade ruminal do amido em milho maduro com moagem grosseira ou fina e SMU de 60,9 a 86,8% da ingestão. Fredin et al. (2015) detectaram variação na digestibilidade ruminal do amido de 75,9 a 85,2% do ingerido para dietas com milho moído diferindo no tamanho de partícula e teor na dieta.

A maior disponibilidade ruminal do amido pode aumentar a produção de proteína microbiana no rúmen, o suprimento de aminoácidos metabolizáveis para o animal, e a eficiência alimentar. O ganho na eficiência alimentar (Leite/Consumo) parece ocorrer por depressão do consumo induzida por maior oxidação hepática de propionato (Allen et al., 2009) em produção de leite similar (Bitencourt, 2012). No entanto, maior degradação ruminal do amido pode indesejavelmente induzir acidez, levando a uma redução na síntese de proteína microbiana, na secreção de sólidos do leite, e na longevidade de vacas leiteiras. A formulação de dietas com grão ensiladas precisa considerar a relação
entre a disponibilidade ruminal do amido e a exigência de fibra em detergente neutro (FDN) fisicamente efetivo.

Vanderwerff et al. (2015) avaliaram a resposta de vacas leiteiras a variação no processamento da forragem de milho. Uma silagem foi colhida com uma máquina com rolos convencionais (2 mm de abertura) e outra foi colhida com rolos do tipo “shredlage”. A silagem shredlage teve proporção de partículas abaixo da peneira de 8 mm do separador da Penn State semelhante à silagem convencional (27,2 vs 24,8 %, respectivamente), mas teve maior proporção de partículas acima de 19 mm (18,3 vs 7,1 %) e menor proporção de partículas entre 8 e 19 mm (54,5 vs 68,1 %). Maior proporção de partículas acima de 19 mm não foi relacionado a maior tempo de ruminação por dia ou por unidade de FDN ou MS. Estes dados sugerem que o teor de FDN acima da peneira de 8 mm do separador de partículas da Penn State (peFDN_{>8}) é uma medida suficiente do teor de FDN fisicamente efetivo da dieta. Uma boa discussão sobre o conceito de peFDN_{>8} pode ser obtida em Zebeli et al. (2012).

A estimativa do teor de amido degradado no rúmen (AmiDR) é um parâmetro que pode aumentar a acurácia na formulação da dieta. O modelo do CNCPS v.6 (Tylutki et al., 2007) adota um modelo de 1 pool para predizer a degradação ruminal do amido (Fração B1 de carboidratos) adotando kd variando de 10 a 30 %/h [AmiDR = Amido × kd / (kd + kp)]. O modelo do CNCPS usa a equação de predição do kp de concentrados para predizer o kp do amido no rúmen (kp = 1,169 + 1,375 × FpBW + 1,721 × CpBW. Onde, FpBW = Consumo de MS de forragens como % do peso vivo e CpBW = Consumo de MS de concentrados como % do peso vivo). As recomendações de kd do amido no banco de alimentos do AMTS são 10 %/h para milho maduro moído grosso, 15 %/h para milho maduro moído fino, e 30 %/h para SMU com 24 % de umidade. Os valores de kd não são mensuráveis por técnica laboratorial rotineira e são alocados ao alimento de forma empírica pelo nutricionista.

Uma metodologia laboratorial que aumente a acurácia da predição de AmiDR parece ser neccessária. Um modelo de degradação do amido considerando pools A (Instantaneamente degradável) e B (Lentamente degradável) e valores de kd da fração B estimáveis em laboratório pode ser mais adequado. Lopes (2017) demonstrou que o teor de fração C (Indigestível) é praticamente nulo no milho. Esta autora fez incubações ruminais in situ de amostras de milho finamente moído por 240 horas e obteve valores da fração C de 1,0 % da MS e do amido.
Efeito de silagens de grãos na digestibilidade e desempenho de vacas leiteiras

O efeito da maior digestibilidade ruminal dos grãos sobre o desempenho e o consumo de MS de vacas leiteiras parece ser dependente do teor de amido na dieta. Quando comparado a milho maduro finamente moído (MFM), a SMU (37 % de umidade) reduziu o consumo de MS de uma dieta com 32 % de amido, mas não afetou o consumo de uma dieta com 21 % de amido (Oba e Allen, 2003a). A dieta de baixo amido foi formulada por substituição de MFM por uma mistura 50:50 de silagem de alfafa e silagem de milho. A dieta de amido alto aumentou a produção de leite corrigida para sólidos em comparação com a dieta com baixo amido quando as vacas foram alimentadas com MFM (+ 3,3 kg/d), mas não para vacas alimentadas com SMU (+ 0,7 kg/d). Alto amido reduziu o teor de gordura do leite com SMU e não teve efeito sobre o teor de gordura com MFM. Oba e Allen (2003b) observaram que a diferença na digestibilidade ruminal do amido entre SMU e MFM em dietas com alto e baixo amido foram de 24,2 e 12,6 unidades percentuais, respectivamente, mas a mudança na digestibilidade aparente do amido no trato total foi de apenas 1,6 e 0,3 unidades percentuais. A ação compensatória dos intestinos na digestibilidade do amido reduz a diferença na digestibilidade ruminal entre dietas variando em teor e processamento do milho. Pequena diferença na digestibilidade do amido no trato digestivo total pode ocorrer entre dietas com grande diferença na proporção do amido digerido no rúmen ou nos intestinos (Nozière et al., 2014; Fredin et al., 2015). O efeito da ensilagem dos grãos sobre a digestibilidade do amido no trato total é pequena em comparação ao efeito do processamento sobre a partição da digestão entre rúmen e intestinos.

Bitencourt (2012) avaliou o efeito da SMR sobre o desempenho e a digestibilidade de nutrientes em vacas leiteiras. Os tratamentos foram MFM, SMR com 43,7 % de umidade e ensilado por 358 dias, e milho extrusado (ME). O teor de milho na dieta foi de 17 % da MS e o teor de amido foi de 27,2 % da MS em todos os tratamentos. Quinze vacas Holandesas receberam uma sequência dos 3 tratamentos em quadrados latinos 3 × 3 com períodos de 22 dias. Os tratamentos não afetaram a produção de leite (33,3 kg/d), mas a ingestão diária de amido foi reduzida em ME e SMR em relação a MFM. A relação entre a produção de leite e o consumo de MS foi aumentada por ME e SMR. O impacto negativo do ME sobre o consumo de matéria seca e as secreções diárias de gordura e energia no leite, sugerem que o processamento do milho por extrusão aumentou mais o amido degradável no rúmen do que o
processamento por ensilagem. A SMR tendeu a aumentar as digestibilidades da matéria orgânica e da FDN e a síntese microbiana no rúmen em relação ao MFM. Os tratamentos não tiveram efeito sobre a digestibilidade do amido no trato digestivo total (média de 95 % do ingerido). Milho armazenado como SMR reduziu o comportamento de mastigação, o tamanho das refeições e o teor de N-uréico do leite e aumentou a relação leite/consumo comparado a MFM.

Arcari et al. (2016) avaliaram o efeito da substituição de MFM por SMR sobre a digestibilidade e o desempenho de vacas leiteiras em fase final da lactação. Estes autores forneceram dietas baseadas em cana-de-açúcar (46 % da MS da dieta) e substituíram 0, 33, 66 e 100 % de MFM por SMR em um experimento em quadrado latino 4 × 4 com períodos de 21 dias. A SMR foi ensilada para 90 dias antes do início do experimento e as dietas continham 34 % de milho e 25 % de amido na MS. A substituição do MFM por SMR induziu aumento linear na no consumo de MS (18,3 a 18,8 kg/d) e aumentos quadráticos na digestibilidade do amido (91,0 a 99,0 % da ingestão) e na produção de leite (21,3 a 23,4 kg/d). Quando cana-de-açúcar foi a única forragem na dieta, SMR aumentou a digestibilidade do amido, o consumo e a produção de leite relativamente a MFM.

Variação no tamanho de partícula pode ser uma estratégia para manipular a fermentação ruminal do amido na SMR, como sugerido pelo pequeno aumento na digestibilidade in vitro da SMR sob moagem fina comparada a moagem grosseira quando as silagens foram armazenadas por mais de 30 dias (Lopes, 2017). Recentemente, nós avaliamos o efeito do tamanho de partícula da SMR e do teor de amido na dieta sobre o desempenho e a digestibilidade de vacas leiteiras (Castro, 2017). Grãos maduros de um híbrido de milho de alta vitreosidade do endosperma foram moídos em peneira com crivo de 3 mm (Fino) ou 9 mm (Grosso) para reidratação a 40 % de umidade e ensilagem em baldes de 200 L por 247 ± 24 dias (205 a 289). A taxa de moagem foi 3,9 ton/h para Fino e 11,7 ton/h para Grosso, demonstrando o efeito benéfico do maior tamanho de partícula sobre a necessidade de mão de obra e energia na utilização da SMR. A DEF estimada por incubação ruminal in situ por 0, 3, 6, 18 e 48 h e assumindo um kp de 6,5 %/h foi de 34,2 % da MS para MFM e 63,8 % da MS para SMR. A ensilagem aumentou a fração A (52,0 vs 12,5 % da MS) e tendeu a reduzir o kd (2,03 vs 2,15 %/h) do milho. Apesar do MFM Fino ter sido mais degradado no rúmen do que MFM Grosso, as degradações ruminais in situ de SMR Fino e Grosso foram semelhantes. As dietas foram formuladas para conter 22,1 ou 14,3 % da MS de SMR Fino ou Grosso e foram ofertadas a 16 vacas Holandesas em lactação em quadrados latinos 4 × 4 com períodos de
21 dias. O teor de amido dietético foi reduzido de 29,1 para 23,5 % da MS por substituição de SMR por polpa cítrica. Os tratamentos não tiveram efeito sobre a produção de leite (31,0 kg/d), mas o consumo de MS foi reduzido quando SMR Fino substituiu Grosso na dieta de amido alto. A eficiência alimentar tendeu a ser aumentada por SMR Fino apenas quando a dieta de alto amido foi ofertada, associado a maior teor de D-lactato no plasma, menor pH ruminal e menor digestibilidade da FDN no trato digestivo total do que SMR Grosso com amido alto. Quando a dieta de baixo amido foi ofertada, o tamanho de partícula da SMR armazenada por mais de 205 dias não afetou a digestão, o desempenho leiteiro, o consumo e a eficiência alimentar. Os dados sugerem que a moagem grosseira da SMR reduziu a capacidade acidogênica do amido no rúmen comparativamente à moagem fina e pode ser desejável quando a concentração de amido dietético é elevada.

O efeito do tamanho de partícula da SMR sobre a digestão, o consumo e o desempenho de vacas leiteiras sob pastejo foi avaliado por Batalha (2015). Vinte vacas mestiças Holandês-Jersey foram alimentadas com pastagem de capim elefante e concentrados (2 x/d. 4.30 kg de MS/d) contendo 82 % de MFM (moído com crivo de 2 mm), SMR Fino (moído com crivo de 2 mm), SMR Grosso (moído com crivo de 6 mm) ou milho floculado em quadrados latinos 4 × 4 com períodos de 16 dias. As SMR tinham 35 % de umidade e foram ensiladas por 177 dias. A SMR Grosso reduziu a digestibilidade dos carboidratos não-fibrosos no trato digestivo total comparado a SMR Fino, mas a ensilagem não aumentou a digestibilidade em relação ao MFM. O processamento do milho não afetou o consumo (11,1 kg/d) e a produção de leite (13,4 kg/d). O teor de N-uréico no leite foi aumentado pela moagem grosseira da SMR. Embora a moagem grosseira aparentemente reduziu a degradação ruminal do amido da SMR, o processamento do milho não afetou o desempenho de vacas com baixa produção de leite a pasto.

**Sumário**

A ensilagem de grãos aumenta a digestibilidade ruminal do amido, mas a digestão intestinal compensa a menor degradação ruminal das fontes de amido mais resistentes, resultando em menor variação na digestibilidade do amido no trato digestivo total do que na partição da digestão entre o rúmen e os intestinos.

A maior fermentabilidade de grãos devido à ensilagem pode induzir acidose ruminal. Quando dietas com alto teor de amido são adotadas, milho ensilado
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pode reduzir o consumo sem afetar a produção de leite comparativamente a milho moído. Efeitos a longo prazo de silagens de grãos sobre a eficiência alimentar e a saúde de vacas leiteiras não foram suficientemente avaliados.

Dietas baseadas em silagem de grãos altamente fermentáveis podem exigir maior concentração de FDN fisicamente efetivo na dieta e práticas de manejo alimentar capazes de distribuir a ingestão de concentrados ao longo do dia. A alimentação com concentrados para vacas em pasto pode ser particularmente desafiadora, desde que a frequência de oferta diária de concentrados é normalmente baixa em sistemas baseados em pastagem.

O tamanho de partícula e a duração do armazenamento podem afetar a digestibilidade ruminal de grãos ensilados, mas o efeito negativo do maior tamanho de partícula sobre a degradação ruminal parece ser reduzida quando a duração do armazenamento éalongada.

O armazenamento de grãos na forma de silagem permite compras estratégicas ou cultivo de grãos na fazenda, potencialmente capazes de reduzir o custo alimentar em relação ao armazenamento e processamento de grãos moídos. Moagem grosseira de milho maduro para armazenamento como SMR pode reduzir o uso de mão de obra e energia para processamento de grãos, mas o efeito da moagem grosseira sobre a digestão, desempenho e consumo de vacas leiteiras quando a duração do armazenamento da silagem é menor que 30 dias requer avaliação.

A nutrição deve procurar maximizar a eficiência alimentar de vacas leiteiras em fazendas aproveitando-se da armazenagem de grãos como silagem como uma ferramenta para aumentar a lucratividade.

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A QUALIDADE DA SEMENTE DEFINE A PRODUTIVIDADE E A PERENIDADE DO PASTO

Figueiredo, U. J.¹

Introdução

A pecuária nacional vem passando por constantes mudanças nos últimos anos. Cada vez mais a demanda por tecnologia se faz necessário, haja vista que a pressão da agricultura pelas áreas de pecuária vem aumentando nos últimos anos. É notório o efeito do melhoramento genético animal na produtividade animal, associado por exemplo ao uso de inseminação artificial em tempo fixo. Ademais, a suplementação animal, o uso adequado de insumos nas pastagens (corretivos, fertilizantes, inseticidas, etc.), a aplicação correta de técnicas de manejo do pastejo (lotação contínua, lotação intermitente, etc.) vem contribuindo para aumentar a produtividade da pecuária. Essas mudanças fazem com que os produtores sejam capazes de produzir mais carne e leite com qualidade, reduzindo assim o custo do litro de leite e da arroba de carne produzidos.

Nos sistemas pecuários brasileiros outra tecnologia que o produtor tem disponível e deve estar atento é o uso das sementes de qualidade para pastagens. Para as espécies de gramíneas forrageiras de maior importância econômica no Brasil, pela Instrução Normativa no 30, de 21 de maio de 2008, os padrões mínimos exigidos de pureza (%P) podem variar de 40% (*Brachiaria ssp.*) a 60% (*Panicum maximum*), e os padrões mínimos da porcentagem de germinação (%G) são de no mínimo 40% (*Brachiaria ssp.*) a 60% (*Panicum maximum*) (BRASIL, 2008). Estes padrões estabelecidos pelo Ministério da Agricultura, Pecuária e Abastecimento (MAPA) estabelecem as normas e os padrões para produção e comercialização de sementes de espécies forrageiras de clima tropical no país.

Usando estes critérios, as empresas brasileiras nos últimos anos vem trabalhando com a definição do Valor Cultural ou comumente conhecido como VC, no qual significa a porcentagem de sementes puras e viáveis, calculadas a partir da multiplicação da %P pela %G. Este modelo tradicional que prioriza a densidade de semeadura (kg de sementes/ha) vem sendo substituído por um outro modelo, o qual busca estabelecer a quantidade de sementes requeridas

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por unidade de área para atingir as populações-alvo (plantas estabelecidas/m²). Neste sentido, cada semente passa a ter um papel fundamental na formação da pastagem, e isto pode determinar a produtividade inicial e a perenidade das pastagens.

A qualidade de sementes tem atenção especial para as grandes culturas como soja, milho, trigo, algodão, etc., também em culturas oleícolas este tema é amplamente explorado. Isso ocorre porque a semente é vista como um insumo que traz retorno em produtividade, onde é possível explorar o potencial genético de uma cultivar, bem como a tecnologia dos tratamentos de sementes que podem agregar mais ainda a resposta na produtividade quando se usa uma semente de alta qualidade na implantação da cultura.

**Qualidade de sementes forrageiras**

O entendimento das características e como a qualidade pode ser afetada explicam a importância do uso de sementes com alta qualidade nos sistemas de produção. A qualidade de sementes pode ser caracterizada pela pureza do lote, a viabilidade, a sanidade e o vigor. Dentre estes, o vigor da semente pode ser destacado como a característica mais importante para mensurar o quanto uma semente pode expressar seu potencial em ambientes da agropecuária.

Em forrageiras tropicais especialmente para as gramíneas, as sementes são colhidas no chão por métodos de varredura, e quando chegam à indústria estão normalmente com menos de 50% de pureza, no qual grande parte do lote contém palhas, torrões, insetos, sementes vazias, etc.

A viabilidade das sementes é definida como a porcentagem de sementes que estão vivas e possuem potencial para germinar, em outras palavras, são as sementes que têm potencial de virar uma planta produtiva na pastagem. Essa viabilidade pode ser avaliada pelo teste de tetrazólio, o qual indica se os tecidos embrionários estão respirando e, portanto, estão vivos (Figura 1, A). Esse resultado é evidenciado pela coloração avermelhada que reflete a atividade da enzima desidrogenase envolvida na atividade respiratória do embrião (Marcos-Filho, 2015).
O vigor da semente engloba as características que determinam a atividade e a performance das sementes em diferentes ambientes que são submetidas (ISTA, 2018). Uma semente que possui um alto vigor tem a oportunidade de se tornar uma planta produtiva e um grande potencial de deixar descendentes num sistema de produção. Em forrageiras quanto maior o vigor de uma semente, maior a chance por exemplo do pecuarista realizar o primeiro pastejo antecipadamente, seja para animais de corte ou para produção de leite. Neste sentido, os testes de germinação são mais utilizados para mensurar quanto um lote de sementes pode apresentar de vigor.

**Potencial do uso de sementes forrageiras de qualidade**

Na pecuária, o uso de sementes piratas ou sementes de baixa qualidade ainda é frequente. Talvez porque o resultado do uso de uma semente de qualidade e que tenha tratamentos exclusivos não sejam imediatos como ocorre nas grandes culturas, as quais possuem os ciclos de produção mais curtos. No entanto, se o produtor medir o quanto ele pode antecipar o primeiro pastejo e ao mesmo tempo ofertar maior disponibilidade de forragem aos animais, este cenário poderia ser diferente.
A qualidade da semente define a produtividade e a perenidade do pasto

Em estudos sobre a produção de biomassa no primeiro corte (simulando o primeiro pastejo) foi comparado o uso de sementes nuas (Sem tratamento – ST) a sementes revestidas com diferentes formulações (T1, T2, T3 e T4), foi possível verificar um aumento na produtividade de massa seca por hectare (PTMS), tanto para cultivares tradicionais como a cv. Marandu (Brachiaria brizantha) quanto para novos genótipos em teste como híbrido de Brachiaria ssp. (Figura 2).

![Figura 2](image)

**Figura 2** - Produtividade total de massa seca (PTMS) no primeiro corte de cv. Marandu e novo genótipo (Híbrido) de Brachiaria ssp. a partir de sementes sem revestimento (nua) e com quatro diferentes tipos de formulações no revestimento. Médias dentro de cada genótipo seguidas pela mesma letra não diferem entre si pelo teste de Skott-Knott (P < 0,05).

Para a cv. Marandu, o uso do T1 permitiu uma PTMS de 45% a mais do que a semente sem tratamento, já para o genótipo melhorado estes ganhos podem chegar a 2,2 vezes em média a mais do que sementes sem tratar. Isto no campo representa um aumento na produção variando 1,2 a 3,0 ton MS.ha⁻¹ com o uso de novas tecnologias disponíveis no mercado.

Com essa possibilidade de agregar valor a semente por meio do revestimento de sementes, torna-se possível potencializar uma semente de alta qualidade para que ela germine e produza uma planta sadia e produtiva. Este incremento na produtividade possibilita produzir de 1,0 @/ha a 3,0 @/ha somente no primeiro pastejo, a qual cobre os custos de investimentos realizados para se ter uma semente de alta qualidade na implantação do pasto na propriedade.
Sumário

Desse modo, o uso de sementes de forrageiras de alta qualidade é de grande importância, pois cada vez mais é notório a importância do uso de tecnologias que aumente a produtividade dos sistemas de produção e consequentemente a lucratividade. Mas é importante ressaltar um esforço conjunto de cientistas, técnicos e pecuaristas para aplicar corretamente as técnicas do manejo do pastejo, para explorar o máximo potencial da forrageira, bem como capitalizar o que uma semente de qualidade pode produzir a mais em detrimento do uso de sementes de baixa qualidade.

Referências


NEW FERTILIZER TECHNOLOGIES AND THE MANAGEMENT OF SOIL FERTILITY IN PASTURES

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Introduction

Pasture fertilization has been reported as an alternative for the intensification of animal production since the 1970s in Brazil (Santos et al., 2010). However, despite the importance of soil fertility management for sustainable pasture production systems nearly 50% of pasture lands in Brazil are degraded, mainly due to inadequate soil management (Martha Júnior & Vilela, 2007). The recommendation criteria for pasture fertilization need some adjustments, especially for new and productive forage species and production systems adopted, that generate a satisfactory economic return to the farmer when properly adopted (Santos et al., 2010). However, the use of liming materials and fertilizers in soil fertility management in pasture is not widely used and most farmers consider the reduction in support capacity and loss of productivity as an inherent pasture phenomenon over time (Martha Júnior et al., 2007a). In this chapter, information on soil fertility management for pasture production, integrated system fertility management, and new fertilizer technologies with potential application for pasture will be presented.

Soil testing

Chemical soil analysis (soil testing) is the main tool for assessing soil fertility and recommending liming materials and fertilizers. With soil testing it is possible to evaluate the availability of nutrients and the presence of toxic elements that can reduce forage productivity and quality. A routine analysis includes: soil reaction (pH); organic matter content; available phosphorus and potassium; exchangeable calcium and magnesium; potential acidity (H+Al), exchangeable aluminum (Al^{3+}); micronutrients (B, Cu, Zn, Fe, Mn) and soil texture. For analysis interpretation, one should be careful with the methods used and the units that results are expressed, as this directly influences the

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recommendation. For forages, the recommendation is usually based on technological levels of management (e.g. high, medium and low).

**Liming**

Liming is the technique used to correct soil acidity, improving cropping conditions and increasing fertilizer use efficiency. The limestone when incorporated in the soil reacts with the acid components and neutralize them, as a result there is an increase in soil pH and exchangeable calcium and magnesium contents as well as an equilibrium in soil chemical properties. The most used methods for limestone recommendation are: (1) basis saturation method, which aims to raise base saturation to an ideal value for the cultivated species (between 30% and 60% for forage grasses); (2) method of Al³⁺ neutralization and raise the levels of Ca²⁺ and Mg²⁺; and (3) method that aims to raise the pH to an ideal value for the cultivated species (Santos *et al.*, 2010; Vilela *et al.*, 2007a).

**Gypsum**

Gypsum application is used for the correction of calcium deficiency and to reduce aluminum toxicity in the subsurface (>20 cm). Therefore, it favors the root system to grow deeper, which increase plant resistance to drought periods and improve nutrient use efficiency. For pastures it is recommended to apply gypsum when the aluminum saturation is higher than 20% or the calcium content is lower than 0.5 cmolc dm⁻³ at the 20-40 cm layer (Santos *et al.*, 2010). Additionally, all sulfur can be supplied with gypsum application. The recommended amount of gypsum is based on soil texture as follows: Gypsum amount (kg ha⁻¹) = 50 x % clay. Usually, the recommended amount will last for at least five years. Intensive production systems should be monitored by soil testing to check the levels of available sulfur (Vilela *et al.*, 2007b).

**NPK fertilization**

For nitrogen fertilization there is no indicator that defines the level of nitrogen (N) in soil. In general, it is recommended to apply 50 kg ha⁻¹ of N in pasture implementation and 40 to 50 kg ha⁻¹ of N yearly for pasture maintenance
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(Santos et al., 2010; Martha Júnior et al., 2007b). Nitrogen doses higher than 60 kg ha\textsuperscript{-1} are not recommended due to increase in N losses (Martha Júnior et al., 2007b). Nitrogen fertilization is the most efficient strategy to accelerate plant development and favor forage yield (Santos et al., 2010). Moreover, N fertilization favors the increase of soil organic matter due to the greater forage production, guaranteeing a conservation of the pasture for longer periods. The strategies to improve N and other nutrients use efficiency in pastures are similar to those adopted for other crops in general, i.e. the right dose and the right source at the right place at the right time.

Phosphorus (P) is one of the most limiting nutrients for agricultural production in tropical soils, since its availability under natural conditions is generally very low (Sousa et al., 2007). On average, only about 20-30\% of P applied as fertilizers is absorbed by plants, causing a low P use efficiency. The other 70-80\% are adsorbed on Fe and Al oxides and on clay minerals or precipitated with Ca. The low P use efficiency occurs mainly due to the cropping in weathered soils and the lack of soil acidity correction (Sousa et al., 2007). For the establishment of pastures can be recommended the addition of reactive rock phosphates, which slowly release P with acid soil solubilization and has a medium- to long-term P fertilization effect. The dose of P\textsubscript{2}O\textsubscript{5} in pasture implantation in soil with a very low P level varies from 40 to 200 kg ha\textsuperscript{-1} depending on the forage species and soil texture, while the application of 20 kg ha\textsuperscript{-1} of P\textsubscript{2}O\textsubscript{5} per year is enough for pasture maintenance (Sousa et al., 2007; Santos et al., 2010).

Potassium (K) is absorbed in high amounts by plants and most tropical soils (especially under cerrado biome) has a very low level of K. Thus, K fertilization is essential to maintain and increase pastures productivity (Vilela et al., 2007c). The critical level of K in pasture soils ranges from 50-60 mg dm\textsuperscript{-3} (0.13-0.15 cmol\textsubscript{c} dm\textsuperscript{-3}), while the K saturation levels should be maintained between 2\% and 4\%, to avoid excess and leaching losses (Vilela et al., 2007c). Potassium fertilization is recommended based on K availability and soil CEC, ranging from 0 to 50 kg ha\textsuperscript{-1} K\textsubscript{2}O (Vilela et al., 2007c; Santos et al., 2010).

**Micronutrient fertilization**

Micronutrient fertilization is essential for obtaining profitable yields for the vast majority of crops (Vilela et al., 2007c). However, the response of tropical forages to the application of micronutrients is not as significant as for
grain crops. But, it is important to replenish micronutrients for high-yielding fodder crops, or even those that are intercropped (Vilela et al., 2007c). Soils with adequate levels of organic matter can provide micronutrients for pasture implantation. On the other hand, soils with low organic matter content are not able to supply micronutrients to ensure high forage yields (Vilela et al., 2007c). The micronutrients recommendation for pasture implantation is still very limited, however, doses of 0.2 kg ha\(^{-1}\) of Mo, 2.0 kg ha\(^{-1}\) of Zn, 2.0 kg ha\(^{-1}\) of Cu and 1.0 kg ha\(^{-1}\) of B are supposedly enough to correct micronutrient deficiencies in pasture soils.

**Soil fertility management in integrated crop-livestock-forest systems**

Due to the great costs required for the formation and reform of pastures, techniques have been sought to reduce costs, to avoid soil degradation and to guarantee the sustainability of agriculture and animal production. In this sense, the rotation system of annual crops with pastures and/or forest species, the so-called integrated crop-livestock or crop-livestock-forest systems, has brought economic and environmental benefits (Freire et al., 2010). The adoption of these systems can benefit either pasture implantation of pasture reform. The forage serves as feed for the animals during the off season and as mulching for no-tillage. Forage crops are very important in these systems, since they contribute to the improvement of the soil physical properties, favor the nutrients cycling and also act as a barrier against invasion of diseases and weeds (Santos et al., 2010).

The integrated systems favor a reduction in the costs of pasture implantation, since forages benefit from the investment made in the implementation of annual crops and use the residual fertilization effect (Freire et al., 2010). Still there are few recommendations of fertilization for integrated systems and thus the soil fertility management is based on the annual crop (Freire et al., 2010). In soils with low fertility it is recommended to fertilize (mainly with P and K) the forage intercropped with the annual crop to obtain a good pasture formation. Conversely, in soils of medium to high fertility levels the fertilization can be done only for the annual crop (Freire et al., 2010).
New fertilizer technologies for pastures

Currently there is a great research effort involving the development of new technologies in fertilizers, mainly for crops with higher economic returns, such as grain crops. Despite the scarcity of research directly related to pastures, the increasing adoption of integrated systems has benefited the forages using these new technologies. The main technologies are related to nitrogen fertilizers of increased efficiency and more recently organomineral fertilizers.

 Increased efficiency fertilizers are those that promote improvements in terms of agronomic efficiency as compared to conventional fertilizers. This technology is mainly focused on nitrogen fertilizers in order to reduce N losses through volatilization. The technologies can be classified as stabilized fertilizers (treated with additives for N stabilization), slow-release fertilizers (chemical modification – e.g. condensation of urea with aldehydes) and controlled-release fertilizers (coating the granule - physical barrier to prevent the diffusion of N) (Guelfi, 2017).

The organomineral fertilizer is the product resulting from the blend or combination of mineral and organic fertilizers. However, in order to be considered an organomineral and marketed as such, the fertilizer must have the following characteristics: moisture ≤ 25%, organic carbon ≥ 8%, cation exchange capacity ≥ 80 mmol\textsubscript{c} kg\textsuperscript{-1} and the sum of primary nutrients (NPK) > 10% (BRASIL, 2009).

Recently, a new approach of fertilizer production is being studied, which is the biochar-based phosphate fertilizers. Biochar is the material resultant from thermochemical conversion of carbon-rich organic residues by pyrolysis. Mineral enriched biochar, either in pre- or post-pyrolysis, is promising to produce enhanced efficiency fertilizers while help to recycle and add value to residues. These fertilizers are a promising technology for the efficient use of P, especially in tropical soils due to the slow release characteristic and addition of stable carbon to the soil. Initial studies have shown that these fertilizers present great potential, mainly due to the high content of P, slow release and the alkaline reaction in acid soil (Lustosa Filho \textit{et al.}, 2017). This slow release characteristic of the available P favors the maintenance of the supply of this nutrient for a long period, guaranteeing the supply and quality of forage for longer periods as compared to conventional soluble fertilizers.
References

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Concept

Grass-legume mixtures for raising domesticated ruminants is not a novel concept in either natural rangeland or cultivated pasture. Nature provides numerous examples around the world (Fabian and Germishuizen, 1997; Diggs et al., 1999) because grass-forb mixtures are generally more productive, provide better nutrition to ruminants, and are more stable (Posler et al., 1993; Sanderson et al., 2007; Muir et al., 2011). Grasses are the dominant component and provide most of the energy while legumes and other forbs are more important as crude protein sources. As the world’s rangelands and pastures face pressure to produce more with less, multi-plant and multi-animal species systems are a sustainable intensification option (Muir et al., 2015). Unfortunately, managing those complex mixtures is rarely as easy as maintaining cultivating grass monocultures for a single ruminant species. Success and failures of pastures containing grass and legume mixes exist (e.g. see Marten et al., 1989). The question is what have we learned and how can we more widely apply these lessons?

Our goal in this review is to identify key concepts that may simplify grass-legume mixture selection, establishment, and sustainable management. There are no silver bullets but, if we are open to what nature demonstrates to us, we are far more likely to translate those lessons into production reality.

Reducing interspecific competition

The frustrations of establishing legumes, whether singly or in multiples, into grass-dominated pasture in the tropics predate 1965. During the 9th International Grassland Congress in Brazil, Coleman and Leslie (1966) reported an “anti-legume” feeling among participants due to the “failure of legumes to provide a stable pasture under grazing either in association with grasses or pure stands.” The same failure to adopt legumes in mixtures was reported for Australia (Gramshaw et al., 1989; Jones, 2003), New Zeland (Sheath and Hay, 1989), sub-Saharan Africa (Thomas and Sumberg, 1995; Sumberg, 2002), and...
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the United States (Matches, 1989; Rotar, 1989). This frustration has lingered as many research institutes reduced their interest in tropical forage genetic resources (Maass and Pengelly, 2001). Despite the ideology behind forage legumes as an essential mixed farming system ingredient (Sumberg, 2002), Shelton et al. (2005) listed several reasons for the lack of pasture legume adoption, including perceived benefit, inadequate technology, and inflexible approaches. Nonetheless, there are success stories that could be adjusted and disseminated and adjusted for wider regions (Lenné and Wood, 2004; Shelton et al., 2005).

Legume seedlings tend to establish more slowly than grasses in new pastures or recovering rangelands (Lowther et al., 1989). Agronomists have rarely selected novel legume germplasm, at least initially, for their seedling or rhizome (in the case of vegetative propagation) vigor, so establishing legume-grass mixtures (Muir et al., 2016) or, even more challenging, interseeding legumes into established grass stands (Muir and Pitman, 2004) has not been a germplasm selection priority. This must change if we are to foster successful mixtures once that germplasm is released commercially. Commercializing legume species and cultivars specifically selected for their aggressive establishment will go a long way to resolve this issue. However, this approach also comes with inherent dangers, including invasiveness and weediness where legumes are not properly managed. Examples include Leucaena leucocephala in the tropics (Osawa et al., 2016) and Sericea lespedeza (Kibis and Buyuktahtakin, 2017) in temperate regions.

Legumes, because they are more palatable than grasses, tend to disappear from grazed pasture mixes, particularly alongside aggressive warm-climate stoloniferous grasses (Alonso, 2016). Ruminants often selectively graze legumes in mixtures because they provide animals with the crude protein that rumen microorganisms need to break down grass fiber. Especially in continuous stocking, legume-grass mixtures eventually end up as grass monocultures; by contrast, intermittently grazing pastures can stimulate legume regrowth and recruitment (Sheath and Hodgson, 1989). An obvious solution is to manipulate animal grazing pressure or access so that legumes and grasses are equally consumed. One approach is to incorporate legume species, and cultivars physiologically adapted, for example, protected regrowth points, to grazing (Curll and Jones, 1989). High-density, short-duration grazing events with long recovery intervals are a pertinent example (Mullenix et al., 2016). Mixing species with contrasting seasonal growth pattern can also reduce inter-specific competition (Hayes et al., 2018).
Selecting less palatable legumes, vis-à-vis companion grasses, is another approach to mitigate this situation which to date has been used unknowingly, if at all. For example, if legumes form woody stalks that cattle avoid or accumulate secondary compounds that lead ruminants to self-limit intake, these will more likely survive, even under heavy grazing pressure. Some forage legumes exhibit relative palatability according to season making them less susceptible to overgrazing during parts of the year. These traits can be as unintentional as dropping leaves during dry seasons (Peters et al., 2000) or strategically accumulating condensed tannin (CT) content during vegetative growth but diluting it at seed maturation for species dependent on epizoochory (Cooper et al., 2014). Understanding these traits and their seasonality can facilitate management that leads to greater legume persistence.

Canopy and root structure differences among grasses and legumes in mixtures can also dictate legume persistence. Greater root and rhizome mass as well as more prostrate above-ground growth habits, for example, favor legume persistence under grazing (Mullenix et al., 2016) but may also affect light interception and soil nutrient and moisture capture dependent on plant height or root depth, respectively (Zilverberg et al., 2016).

Increasing Synergism

a. Synergy between grasses and legumes

Synergism happens when the total effect is greater than the sum of the individual effects. Grasses and legumes might have synergistic effects regulating above and belowground processes. In this case, synergism will depend on the grass and legume species as well as the process they affect. For the discussion in this section, legumes can be sub-divided into tree legumes or herbaceous legumes. These two types might have different synergisms with grass species, affecting plant responses as a result.

Aboveground processes

Grass and legumes with different morphology might enhance resource utilization, offering pasture managers potential synergy. Grasses typically present erect leaf blades and inflorescences while legumes commonly present horizontal (flat) leaves and branching (Schwinning and Parsons, 1996). This complementary morphology might enhance light interception and reduce weed infestation. In addition to spatial heterogeneity complementing resource
utilization, differences in growth timing also lead to enhanced primary productivity due to a synergistic effect on complementary resource utilization. Multiple grass-legume mixtures will have greater growth heterogeneity throughout the year during different seasons, enhancing aboveground productivity as a result (Skinner and Dell, 2016).

Aboveground biomass in a pasture setting either is grazed or return to the soil as litter deposition. If grazed, grass-legume mixtures will typically result in better feed for ruminants than grass monocultures, especially C4 warm-climate grasses. Plant species richness and voluntary intake by sheep, for example, has an asymptotic relationship (Wang et al., 2010), indicating the maintenance of a diverse diet to sustain animal performance. In addition, excreta output from livestock grazing grass-legume mixtures will likely have a different composition than the excreta from ruminants grazing C4 grass monoculture. In some cases, if the legume has secondary compounds, the fecal decomposition can be slower (Lima et al., 2016). In other cases, when secondary compounds are not found in high levels, dung decomposition can be faster from legume-fed cattle because of greater dung N concentration (Lira, 2013; Khomann, 2017).

Litter deposition and decomposition is a major nutrient cycling pathway in grasslands (Dubeux et al., 2007). The quality of C4 grass litter is a major cause of pasture decline; high C:N ratio and slow decay rate lead to N immobilization and reduction of primary productivity of warm-climate grasslands (Boddey et al., 2004). Grass-legume pasture litter typically has better quality, with faster decay and nutrient release, which improves nutrient utilization efficiency by accelerating nutrient cycling (Cantarutti et al., 2002; Silva et al., 2012). In addition, forage legumes are known for their capacity to associate with N2-fixing organisms, which might help not only legumes but also companion grasses (Dubeux et al., 2017b; Jaramillo et al., 2018; Santos et al., 2018).

Tree legumes provide shade, which affects grass development and nutritive value. Shade typically reduces grass growth (Perry et al., 2009) but its effect on forage quality is not as clear. Shade typically reduces tillering, promotes stem elongation—that may increase in lignin and cell wall concentration—, reduces soluble sugars, and increases N concentration on C4 grasses (Coleman et al., 2004). Legumes and C3 grasses have a greater competitive advantage over C4 grasses in shaded environments compared to full sun. Therefore, it is reasonable to think that grass-legume mixtures might have better chances to persist under partially shaded environments (e.g., silvopasture systems) as opposed to full sun. This is a niche that needs to be better explored by land managers, especially when using silvopasture systems.
Belowground processes

Synergism between legumes and grasses affecting belowground processes might include: i) enhance primary productivity and residue deposition (Nyfeler et al., 2011; Skinner and Dell, 2016); ii) enhance soil organic matter buildup (Fisher et al., 1994); iii) enhance soil organic matter decomposition; iv) explore different soil layers with complementary nutrient and water use (Skinner et al., 2006); v) root-mycorrhizae network sharing resources (e.g., water, nutrients) within the plant community (Hamel and Smith, 1991); and vi) hydraulic redistribution (Prieto et al., 2012). Grass-legume mixtures store belowground N in root-rhizome mass (Santos et al., 2018) that might enhance belowground plant tissue turnover.

Competition for natural resources (e.g., water, nutrients) between grasses and legumes is possible (Dubeux et al., 2017a). Tree legumes might increase synergism with grasses if compared to herbaceous legumes, notably spatial root distribution and nutrient recycling from deep soil layers (Menezes and Salcedo, 1999). Shade provided by tree legumes might also affect soil temperature and alter decomposition processes (Gea-Izquierdo et al., 2009).

Rumen microorganisms

Grass-legume mixtures might also present synergism during rumen microbial degradation. Nitrogen-rich legumes might enhance N-poor C4 grass degradation by rumen microbes. Pereira Neto (2017) observed increased digestibility of Tifton-85 bermudagrass (Cynodon spp.) with increasing levels of alfalfa (Medicago sativa L.) in the diet, demonstrating the synergism between grass and legumes during ruminal degradation. Legumes containing secondary compounds such as CT might present contrasting effect, depending on the concentration in the diet (Muir et al., 2014). Species-rich mixtures with greater diversity might offer forage containing CT as well as other feed with very low CT concentration. The right balance of these species in the diet will create synergism, with the ultimate goal of optimizing gross energy provided by both legume and grass components.

Understanding Nutritive Value

Forage nutritive value was historically based on maximum forage voluntary intake and its digestible energy (Crampton et al., 1960), measured using in vitro fermentation techniques (Donefer et al., 1960). While this approach may be
acceptable to determine nutritive value of individual forage components (e.g., fiber), it does not account for associative effects among legume-grass pasture components that may end up, in practice, yielding greater nutritive value to the ruminant.

Grasses and legumes have different physical-chemical properties that preclude the development of a universal method to determine their nutritive value. Such properties include the presence of anti-nutritive factors, also known as secondary compounds (metabolites) or phytochemicals, that vary from genus to genus or even among species, are more frequent in tropical forages than temperate forages, and are more predominant in woody perennials than herbaceous annuals (Jones, 1994; Norton, 1994a; Muir et al., 2009). Although legumes have a multitude of anti-nutritional factors and, in general, their quantities are greater than grasses, the latter also contain anti-nutritional factors such as endophytic and saprophytic fungi, though in smaller quantities than legumes, which impair animal performance (Waghorn and Clark, 2004).

When fed alone or as the principal ingredient, legume anti-nutritional factors may decrease dietary nutritive value even further than when combined with other forages or supplements (Norton, 1994b). Such associative effects include energy loss reduction in the rumen and, possibly, in the hindgut, nutrient escape from the rumen, anthelmintic properties, among many others. For example, most studies designed to explain potential CT impacts in ruminants show benefits and drawbacks that have stimulated conceptual models to document the mechanisms of action of CT (Tedeschi et al., 2014; Tedeschi and Fox, 2018). These models sketch only the nutritional effects of CT consumed by the ruminant animals; more holistic models should include agronomic factors to forecast forage CT type and yield, which combine to determine the biological effect (Naumann et al., 2014). Norton (1994b) supports this by predicting that “new problems will arise with each new species that shows agronomic promise, and careful evaluation of the nutritive value of each introduction needs to be made.”

**Developing Wholistic Understanding**

With this holistic approach in mind, Johnson et al. (2003) developed a hierarchical biophysical model (Sustainable Grazing Systems Pasture Model; SGSPM) to describe and analyze pasture systems on different soil types and under specific grazing management (e.g., set-stocking, rotational grazing,
continuous grazing). The SGSPM accounts for forage species (e.g. perennial, grass, or legumes) growth due to climatic conditions (light, temperature, soil water, and nutrient status), water dynamics (e.g., soil water infiltration and drainage, runoff, transpiration, evaporation), predation by grazing ruminants, as well as energy (metabolizable) and nutrient (organic and inorganic) availability to the ruminant animal under different physiological conditions (pregnancy, lactation, and growth). In particular, SGSPM pasture mass accumulation is based on a simplified version of crop growth models delineated by Johnson and Thornley (1983), Johnson and Parsons (1985), and Parsons et al. (1988). Other, perhaps more suitable, grassland models exist (Thornley, 1998) that might provide additional information. The idea of using modeling processes to assist with legume persistence to improve animal production is not new. Rotar (1989) even suggested that modeling could help us to ask the right questions about grass and legume foraging. Such technology can be combined with global positioning system (GPS) and geographic information system (GIS) to gather and analyze spatial data of forage quality and quantity of a particular basin to enhance animal grazing allocation and supplementation, and forage management.

Given the contemporary need to explore options and solutions for food security, climate change adaptation, and greenhouse gasses mitigation (Holzworth et al., 2014), we need more inclusive and holistic models. Developing more comprehensive mechanistic models is not problem-free; increased complexity in the development, evaluation, deployment, and application phases might hinder the models’ practical (and theoretical) uses. The Agricultural Production Systems Simulator (APSIM), for instance, included the GRAZPLAN livestock-pasture systems modeling contributions (Donnelly et al., 1997; Freer et al., 1997; Moore et al., 1997) but forage anti-nutritive effects (specifically from legumes) to the ruminant animal are limited. Additional challenges to livestock-pasture modeling include pasture biodiverse ecosystems, ruminant animals’ additive trophic level, and the natural interaction between animals and forage (random nutrient flows) (Snow et al., 2014). Furthermore, the animal’s selective grazing behavior in legume-grass mixtures is an additional complexity that is often neglected in many livestock-pasture models. Diverse management used around the world likewise prejudices agronomic factor forecasting as driven by legume anti-nutritional factors.
Developing new legume germplasm

Persistence and nutritive challenges in grazed legume/grass mixtures point to the need for additional legume germplasm development and management techniques. Some (Barrett et al., 2015) argue that this should focus on currently important species, i.e., improving what we have already domesticated. Others believe that looking at new species native to the target areas will get us further faster (Smith et al., 2010). Especially in tropical and sub-tropical regions, many of these native herbaceous and browse legumes have yet to be fully considered with regional exceptions (Azevedo et al., 2016; Calles et al., 2017). Both approaches likely have merit, depending on locations and production goals, as long as establishment, persistence and ruminant nutrition traits with grass-legume mixtures are used as selection traits.

Forage legume geneticists have new tools to assist in shortening the time between research and commercialization. Molecular markers, for example, based on genetic material, rather than tedious and sometimes misleading phenological characterization, can quickly identify distinct, ecotypic populations with the adaptations to local environments as well as desirable pasture characteristics. Genetic maps can save time and effort (Staub et al., 2016). These techniques can rapidly identify genetic lacunae and endangered species or populations (Azevedo et al., 2016; Calles et al., 2017).

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Nitrogen cycling in Brachiaria pastures: The key to understanding the process of pasture decline. Agric. Ecosyst. Environ. 103:389–403.


New perspectives on forage legumes in mixed pastures


Grasslands are among the largest ecosystems in the world and account for 25% of the earth’s surface (Reid *et al.*, 2008). Peters *et al.* (2013) reported that forage is the most consumed livestock feed in the world, which illustrates the need for understanding sustainable land management strategies for supporting global animal production. Grasslands are multi-functional systems that require an understanding of soil, plant, animal, and climate considerations to optimize production potential. Management of warm-season pasture systems requires a systems-approach to production. In warm climates, there are several challenges and opportunities to improve the viability and production capacity of these systems.

**Challenge: Improving Productivity – Amount of Quality Forage Produced per Unit Land Area**

**Opportunity: Managing for Soil Health**

The area of soil health has emerged as an area of foundational importance in pasture management systems. Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. There is an opportunity to define management practices that improve water infiltration, retention, nutrient cycling, soil stability, and support. Extensive work has been conducted on fertility recommendations for maximizing production of *Panicum* and *Brachiaria* sp. (Fernandes *et al.*, 2014;). Next-step research to build on this information may be to determine optimum levels of fertility that benefit the soil structure, flora, plant and animal production collectively. Economically sustainable levels of fertilization have been identified, but the collective impacts of this level of management on physical, chemical, and biological properties of soil in warm-climate systems are not well defined. Research in the area of ecosystem services has demonstrated the positive impacts of grazing management, which includes grazing intensity,

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frequency, and method, on the role of carbon and nitrogen sequestration potential of pasture systems. Franzluebbers and Stuedemann (2002) stated that pasture management systems in the southeastern USA stimulate greater stratification of SOC than conservation tillage practices, illustrating the potential inputs provided by these systems. Species effects may also play a role in the C sequestration potential of grasslands. Warm-season perennial grasses ($C_4$ photosynthetic pathway) have been proposed for use in the improvement of SOC in grasslands because they produce extensive root systems and provide permanent vegetative cover (Conant et al., 2001). These effects may influence soil organic matter accumulation, nutrient holding capacity, infiltration, and plant productivity in pasture systems, which are all indicators of soil health. Russell and Bisinger (2015) noted that while soil organic matter and water-holding capacity of soils is greater in grazed- than nongrazed grasslands, results of studies evaluating different grazing management systems on soil OM are limited and inconsistent. The authors reported that although grazing management may enhance ecological services provided by grasslands, environmental responses within the system such as climate, soil, landscape, and the inherent plant community influence these responses. A single grazing management strategy may not maximize livestock production and potential ecological services provided by grasslands, thus, these goals must be integrated to define the optimal grazing management system (Russell and Bisinger, 2015).

**Opportunity: Understanding Pasture Stand Health Indicators**

Forage pasture height, canopy light interception, and morphological characteristics are often used as measures to make grazing management recommendations to stakeholders. Providing livestock producers with pasture canopy production indicators creates awareness and provides educational tools for improving pasture management. Pasture management systems are dynamic in nature, and while these measures are beneficial, these indicators should not be considered static or fixed measures for maximizing forage production and utilization, nor should they be used exclusively or independent of one another. Pinto (2000) reported that leaf senescence of bermudagrass under high grazing pressure varied based on herbage accumulation rate throughout the growing season. Because of this, Corsi (2001) suggested that tropical grass management recommendations should be established on characteristics other than tissue flows. Changes in growing conditions and weather characteristics during the season will alter pasture growth rates. Using fixed rest periods can result in early defoliation where the pasture did not achieve its potential, or late defoliation
which is characterized by excess stem accumulation and increased dead material. Both of these scenarios may result in losses in pasture productivity. Relating canopy height and light interception as a tool that can be used in the field by farmers has produced variable results based on level of management, season, and forage genotype being evaluated (Fagundes et al., 2001; Gomide and Gomide, 2013). Wallau et al. (2016) reported that initiation of grazing limpograss at 80% canopy light interception resulted in more frequent grazing events, a longer grazing season, shorter pre-grazing canopy height, and greater leaf percentage compared with 95% canopy light interception in Florida (USA). These results suggested that grazing could be initiated at a pre-grazing canopy height of 60 cm, which was before 95% canopy light interception would have occurred. Gomide and Gomide (2013) suggested that morphological characteristics should not be separated from physiological measures when making pasture defoliation decisions. Instead, emphasis on maintenance of adequate growth and nutritive value in order to keep animal and pasture performance high is a reasonable goal. Use of pre- and post-grazing canopy height measures, relative canopy ground cover, light interception, and species composition as canopy targets should be used collectively to develop a pasture assessment tool for on-farm pasture assessment rather than using singular parameters for evaluating and improving pasture production potential.

**Opportunity: Selecting Forages Adapted to the System**

Since the 1970s, *Brachiaria* and *Panicum* spp. contribution to Brazilian pasture systems has increased significantly. Plant breeding efforts have largely focused on forage accumulation, nutritive value, and disease resistance. Efforts to increase primary productivity and improve plant efficiency should be coupled with potential responses to grazing management when selecting next-step ecotypes for on-farm use. For example, *Brachiaria* grass hybrids such as ‘Mulato II’ have superior nutritive value when compared with other warm-season grasses, but may require more strategic grazing management for long-term persistence. An evaluation of Mulato II, Cayman, and BR02/1794 hybrid brachiaria grass harvested at 3- and 6-wk regrowth intervals in South Florida observed that regrowth intervals of less than 3 wk should be avoided to maintain *Brachiaria* hybrid stands (Vendramini et al., 2014). Pedroso et al. (2017) noted that Mulato II could be maintained under continuous stocking and achieve greater total seasonal herbage accumulation, but require maintenance of the canopy height at 20 to 30 cm. These data illustrate that improved varieties may have greater herbage accumulation and nutritive value compared
to more native or well-adopted species, but require strategic management for longevity in on-farm settings. One step to improving overall forage production potential is to carefully select improved varieties that will meet production goals. When considering pasture species improvement, starting with the right forage species and variety for a given operation is critical. Adoption of forage systems research recommendations could be packaged into input categories to more clearly demonstrate to producers their management options. Defining current forage work as low-, medium-, or high-input systems based on fertility, grazing management, insect and disease pressure, and persistence parameters may enhance the ability of information to be disseminated and applied on on-farm settings.

### Challenge: Meeting Animal Demands through Year-Round Forage Management

**Opportunity: Improving Forage Use Efficiency**

The strategic use of grazing management is an opportunity to improve forage utilization. Species such as *Panicum maximum* have growth rates of 130 to 200 kg DM/ha/day during the active growing season, which presents a challenge for the grazier in terms of managing rapid growth (Corsi *et al.*, 2001). In the Southeast US, cost and ease of management of summer annual grasses such as pearl millet and *Sorghum* sp. have limited their use on beef operations, although there may be forage nutritive value benefits relative to warm-season perennials adapted to the region. Changing the grazing frequency and/or intensity of pastures may alter forage utilization, quality, and potentially animal performance in warm climates. Under continuous stocking, grazing intensity is one of the primary factors that influences forage productivity. Santos *et al.* (2013) evaluated the influence of grazing intensity on *B. decumbens* herbage accumulation under simulated continuous stocking. When pastures were managed to an average height of 15 cm during the winter and 25 cm during spring growth, forage accumulation increased (25.6 t DM/ha) compared with a target stubble height of 25 cm throughout the year (22.2 t DM/ha). This additional growth may increase the stocking rate potential of pastures during the spring and summer seasons. Pedreira *et al.* (2018) evaluated the effects of variable or fixed rest periods on forage production, plant composition, and canopy characteristics of Tifton 85 or Jiggs bermudagrass under rotational
stocking. Pre-grazing canopy light interception was similar among the two cultivars; however, Jiggs had greater stem proportion, canopy height during grazing, and lower leaf area index than Tifton 85. No differences were observed in total yield, which suggests that fixed or variable rest periods can be used for Tifton 85 or Jiggs bermudagrass. The authors noted distribution of plant-part components in the aboveground sward influence forage nutritive value and regrowth potential due to differences in post-grazing canopy composition, and should be considered when determining frequency of rotation in pasture systems.

**Challenge: Managing Nutrient Cycling in Warm-Climate Pasture Systems**

**Opportunity: Inclusion of Legumes to Improve Sward and Litter Quality**

Vendramini *et al.* (2007) suggested that one way to improve nutrient cycling in pasture systems is to utilize grass-legume mixtures. This system can support moderate stocking rates and improve the quality of plant litter deposition, which may decrease nutrient losses in the system compared to grass monocultures. The addition of legumes improves pasture quality and growth distribution during the year, which may result in a system that can extend grazing during the year. Successful examples of the use of legumes include *Brachiaria brizantha*-*Arachis pintoi* mixtures (Tamele *et al.*, 2017). However, establishment and management of legumes in warm-climate systems is not without challenges. While mixed grass-legume systems have high nutritive value, their use in tropical regions has been limited by poor establishment and persistence characteristics (Shelton *et al.*, 2005; Muir *et al.*, 2011). More extensive management systems may be more limited in the use of legumes due to lack of ability to implement improved grazing management practices. Adoption of this technology may be better suited for smaller stakeholder operations where controlled grazing can be used.

**Opportunity: Supplementation on Warm-Season Pastures to Improve Nutrient Recycling**

Supplementation is an indirect way that nutrients can be brought into grazing lands (Vendramini *et al.*, 2007) and may be a strategy to extend grazing during the fall and early winter months in warm climates. During this
time, warm-season grass nutritive value is declining, and animal performance responses are primarily a function of supplementation type and level rather than a reflection of forage quality. However, although forage quality may be low, animal nutrient cycling in this system may contribute towards soil quality and fertility needs. A 2-yr study with dried distillers grains supplementation as a substitute for nitrogen or phosphorous fertilizer with stocker cattle grazing Plains Old World bluestem in Oklahoma (US) observed that N recovery, animal body weight gain, average daily gain, and gain/ha were greater for systems supplemented with DDGS compared with a conventional N or N/P fertility program (Gunter, 2014). Movement of the supplemental feeding area throughout the pasture system is critical for more uniform nutrient distribution in this system, and may pose a logistical challenge for feeding large groups of animals, moving equipment through wet areas, and labor considerations. Further evaluation of supplementation delivery form may be needed (i.e. pressed blocks, feed cubes, tubs) to ease logistics and labor associated with winter feeding while providing an option that can be moved or placed more strategically in the pasture system.

**Summary**

1. Improving warm-season pasture systems requires a systems-approach to forage management. To date, most research projects have focused on individual components that can improve forage management on-farm (height, light interception, etc.), but a collective approach to using soil, plant, and animal measures as on-farm indicators is beneficial.

2. Improving forage production potential and utilization may extend the grazing season for beef producers. In practice, this requires altering grazing intensity and frequency in response to plant growth parameters and is not always a fixed entity.

3. Maximizing nutrient return in grazed ecosystems is important, especially in low-input management systems. Nutrients are cycled both from the animal and plant systems. Diversifying sward contribution with the inclusion of legumes, and altering animal grazing behavior (using supplemental feeds) may improve both components of the system.


BOI 777: QUAL É O PAPEL DA FORRAGEM NESTE SISTEMA?

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Introdução

O Conceito Boi 777 foi desenvolvido para que o produtor pense na Fazenda como uma empresa rural, a qual deve ter metas de produção. Permitindo que, a partir desse pensamento, ele possa traçar estratégias individuais para alcançar a meta esperada que, neste caso, é abater um animal com aproximadamente 21@ (7@ em cada fase) com 24 meses de idade. Para alcançar estes resultados, diversos cenários têm sido estudados na Agência Paulista de Tecnologia dos Agronegócios (APTA/Colina) e em outras Instituições, simulando diferentes estratégias nutricionais, e abrangendo todas as fases da vida do animal (cria, recria e terminação).

Como é de conhecimento geral, a produção de bovinos de corte no Brasil ocorre, predominantemente, em pastagens, as quais apresentam sazonalidade de produção, com maior produtividade e melhor qualidade no período das águas, devido a fatores como: temperatura, fotoperíodo e chuva e condições inversas no período da seca. No entanto, mesmo no período das águas, quando o balanço entre a exigência do animal e a oferta de pasto fica mais próximo do ideal, o animal não consegue expressar todo seu potencial genético para ganho (Roth et al., 2017; Sampaio et al., 2017). Para tal, dentre outras estratégias, há necessidade de conciliar um adequado manejo da pastagem com a utilização de recursos suplementares, permitindo contornar as limitações nutricionais da dieta basal, o pasto (Detmann et al., 2010).

Posto isso, muito se escuta sobre suplementação quando se fala do Conceito Boi 777, no entanto, para alcançar as metas de produção, deve ser dada importância, primeiramente, para a dieta basal, já que o sucesso dos sistemas de produção de corte “tradicionais”, indiferente da fase de vida do animal, se dará em função do sinergismo entre o manejo da pastagem e a suplementação. Dessa forma, nos próximos tópicos, tentaremos responder o título dessa palestra, entendendo qual a contribuição do pasto na obtenção das @ do Boi 777, em cada fase da produção (cria, recria, terminação).

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Boi 777: qual é o papel da forragem neste sistema?

A importância do pasto nas primeiras 7@

A fase de cria compreende a produção de bezerros e bezerras (do nascimento à desmama), mas também as matrizes, novilhas aptas à cobertura e reprodutores. O intuito é desmamar os animais com as primeiras 7@, no entanto, esta fase muitas vezes é negligenciada pelos produtores. Nessa etapa, o pasto possui grande importância, já que a vaca usa a forragem como principal fonte de alimento para produzir o leite. Neste momento também ocorre a introdução de alimentos sólidos aos bezerros (as), seja forragem ou suplemento (através do creep-feeding). O creep-grazing (forragem de melhor qualidade oferecida apenas aos bezerros) também pode ser utilizado como estratégia para introduzir a forragem e aumentar o peso à desmama dos animais.

É importante aqui, fazer um parêntese sobre a alimentação do bezerro, além do leite. A intensificação da cria deve ser considerada sob dois aspectos cruciais: primeiro, esta é uma fase de máxima eficiência de deposição de tecidos e, segundo, qualquer tomada de decisão deverá considerar a alimentação futura do animal.

A curva de crescimento animal possui forma sigmoide, sendo que a primeira parte da curva é a fase de aceleração, com rápido crescimento e multiplicação de células musculares. Parte desse momento do crescimento ocorre durante o período de cria. A maior eficiência para ganho nesse período está relacionada a deposição de tecido muscular. Nutricionalmente, em termos de Mcal consumida/Mcal depositada, a deposição de proteína é menos eficiente que a deposição de gordura. No entanto, 75% do tecido muscular é composto por água, assim, a deposição de tecido muscular proporciona maior aumento de peso por unidade de massa.

Em relação à alimentação futura, deve-se estar ciente de que o animal apresentará, naturalmente, alta taxa de crescimento na cria, e que na fase seguinte, ao ser desmamado, entrará em um pasto de seca. Ou seja, principalmente ao usar alimentos suplementares na cria, deve-se considerar as próximas fases da vida do animal, esperando-se estratégias nutricionais crescentes, como forma de evitar retrocessos na curva de crescimento animal em momentos futuros, refletindo em inadequada deposição de tecidos e perdas econômicas.

A época de parição também é muito importante para a fase de cria. Este aspecto envolve facilidade na re-concepção da fêmea, já que ao parirem no início da estação de parição terão mais tempo para se recuperarem para a próxima estação de monta. Ao mesmo tempo, bezerros nascidos no início da estação de parição apresentam, além de maior peso ao desmame, maior peso
corporal final e peso de carcaça (Funston et al., 2012). Além disso, estes animais se tornam mais eficientes nas fases futuras do crescimento, o que está provavelmente relacionado com efeitos da nutrição materna durante a gestação (Peres et al., 2017).

De acordo com Cubas et al. (2001), não existem explicações biológicas na literatura para o desempenho superior de animais nascidos no início da estação de parição (primavera/verão). No entanto, estes autores justificam o melhor desempenho destes animais em função da melhora na qualidade e quantidade de pasto, juntamente com o início da ingestão de forragem pelo bezerro, em torno de 60 dias após o nascimento. Outra especulação estaria relacionada à programação fetal, já que a restrição nutricional da vaca, durante a gestação, pode alterar as fibras musculares e os adipócitos intramusculares (Du et al., 2010). Bezerros nascidos no início da estação de parição teriam suas mães ingerindo pasto de melhor qualidade no terço médio da gestação, comparados aos bezerros nascidos ao final da estação de parição.

Ressalta-se, portanto, a importância da adequada nutrição da matriz, já que esta, em determinado momento, precisará melhorar o escore de condição corporal, produzir leite e nutrir adequadamente o bezerro que estará gestando. Assim, a adoção de manejo adequado de pasto, aliado a suplementação, pode resultar em incremento no desempenho do feto e, consequentemente, do bezerro, facilitando a desmama de animais com as primeiras 7@.

A importância do pasto na recria do Boi 777

A recria compreende o período que vai da desmama à entrada dos animais na terminação, sendo esta a fase de maior duração do ciclo pecuário e um dos grandes desafios dentre as metas propostas pelo Conceito Boi 777. Na maioria dos sistemas de produção brasileiros, esta fase ocorre exclusivamente em pastagem e se inicia na época seca do ano.

O intuito é reduzir a recria dos 24 meses de duração, comumente obtidos em sistemas menos intensivos, para um período de, no máximo, 10 a 12 meses. Dessa forma, os animais precisam ganhar em torno de 580 g/dia, a pasto, para cumprir com o proposto. Sendo a sazonalidade da produção e valor nutricional dos recursos basais (forragem), ao longo das estações do ano, um dos fatores que contribuem para a complexidade da gestão do sistema, exigindo estratégias nutricionais e manejos distintos durante este período. Assim, para facilitar a compreensão desta fase, ela será dividida em duas etapas, com características e
demandas diferenciadas, sendo: período de seca (150 dias) e período de águas (210 dias).

**Período de seca: Os desafios nos 150 dias iniciais das segundas 7@**

Ao se iniciar a recría, além do estresse oriundo da desmama, pela separação da mãe, os animais necessitam adaptar-se a uma dieta composta exclusivamente por forragem, precisando extrair dela todos os nutrientes necessários para seu desenvolvimento. Adicionalmente, a forragem neste período apresenta baixos valores nutricionais, com deficiência global de compostos nitrogenados (Detmann *et al.*, 2010) e, ainda, com rebrota comprometida por fatores ambientais, permitindo baixas lotações. Dessa forma, é preciso adotar práticas para minimizar os efeitos da estacionalidade e garantir aporte de forragem, tal como o diferimento do uso da pastagem (Fonseca *et al.*, 2012).

O diferimento da pastagem consiste na vedação de determinada área da pastagem durante o período de chuvas, acumulando massa para o período subsequente. Alguns fatores podem influenciar o sucesso do uso do pasto diferido, destacando-se: a escolha da forrageira, quantidade de área a ser diferida, altura inicial do pasto, duração da vedação, adubação nitrogenada, escalonamento na vedação da área e a taxa de lotação utilizada (Fonseca *et al.*, 2014). No entanto, mesmo em cenários otimistas para o uso do pasto diferido, os animais apresentam desempenho moderado ou apenas manutenção do peso corporal (PC). Assim, para se alcançar a produção de 1 a 2 @ nos 150 dias de seca (meta do Conceito Boi 777), é necessário conciliar o diferimento com a suplementação dos animais.

Durante a seca, o principal nutriente limitante é a proteína bruta (PB) do pasto. De acordo com Detmann *et al.* (2010), no período de seca, com forragem de baixa qualidade, deve-se atingir um mínimo de 8 mg/dL de nitrogênio amoniacal no rúmen, para que os microrganismos ruminais tenham condições de alcançar o platô da fração efetivamente degradada da fibra em detergente neutro, implicando em valores de PB próximos a 7%. Ao mesmo tempo, Detmann *et al.* (2010) verificaram que a maximização do consumo de pasto de baixa qualidade é obtida com 15 mg/dL de nitrogênio amoniacal no rúmen e, para isso, os níveis de PB da dieta total (pasto mais suplemento) devem ser ajustados para o fornecimento de PB em torno de 12%, conciliando a otimização da atividade dos microrganismos do rúmen com o maior consumo de forragem.
Neste sentido, em compilação de dados obtidos em estudos realizados na APTA/Colina (Tabela 1) pôde-se constatar que, no período seco, as respostas entre os níveis de suplementação, em relação ao sal mineral (SM), apresenta repetitividade quanto ao diferencial de ganho em peso. Assim, o ganho médio diário adicional é da ordem de 200 g/animal/dia ao passar do SM para suplemento com consumo de 1 g/kg do PC e de 300 e 380 g/animal/dia ao passar do SM para suplementos de consumo de 3 e 5 g/kg do PC, respectivamente.

Tabela 1 - Ganhos obtidos com diferentes estratégias de suplementação no período seco

<table>
<thead>
<tr>
<th>Suplemento</th>
<th>Ganho médio diário, kg/dia</th>
<th>Peso final seca, kg</th>
<th>Dias para ganhar 1@</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>0,050</td>
<td>0,25</td>
<td>218</td>
</tr>
<tr>
<td>1 g/kg</td>
<td>0,250</td>
<td>1,25</td>
<td>248</td>
</tr>
<tr>
<td>3 g/kg</td>
<td>0,350</td>
<td>1,75</td>
<td>263</td>
</tr>
<tr>
<td>5 g/kg</td>
<td>0,430</td>
<td>2,15</td>
<td>275</td>
</tr>
</tbody>
</table>

Peso corporal inicial = 210 kg. SM = sal mineral *ad libitum*; 1 g/kg = suplemento proteico, fornecido na quantidade de 1 g/kg de peso corporal; 3 g/kg = suplemento proteico-energético fornecido na quantidade de 3 g/kg de peso corporal; 5 g/kg = suplemento proteico-energético fornecido na quantidade de 5 g/kg de peso corporal.

Deve-se destacar que, animais suplementados apenas com SM não atingem a meta de colocar 1 a 2@ no período de 150 dias de seca, sendo necessário usar do recurso da suplementação de forma estratégica para tornar o ganho em peso compatível com o proposto. Contudo, deve-se destacar que, nestas condições, o ganho adicional obtido com os suplementos se aplica de maneira mais efetiva que o ganho absoluto apresentado. E ainda, é necessário que se tenha em mente que o sucesso da suplementação e dos ganhos é dependente da presença do pasto, onde a oferta do mesmo, com estrutura e volume adequados, irá contribuir diretamente para a amplitude dos ganhos absolutos.

Para reforçar a importância do pasto, é apresentada uma simulação com as equações propostas pelo BR-CORTE (2010), utilizando suplementos comerciais, com consumo de 1 g/kg do PC (PB = 50%; nutrientes digestíveis totais [NDT] = 40%) e consumo de 3 g/kg do PC (PB = 25% e NDT = 60%) (Figura 1). Para os cálculos, foram subtraídos, das exigências dos animais, os nutrientes fornecidos pela suplementação e calculada a percentagem da exigência do animal que é suprida via pasto.
Boi 777: qual é o papel da forragem neste sistema?

Figura 1 - Participação do pasto e suplementos no consumo total de matéria seca (MS), proteína bruta (PB) e nutrientes digestíveis totais (NDT) no período seco.

Exigências calculadas a partir das equações propostas pelo BR-CORTE (2010). Peso inicial = 210 kg. ¹Suplemento fornecido na quantidade de 1 g/kg do peso corporal (PC), PB = 50%, NDT = 40%, @ colocada 1,5 e ganho médio diário = 0,300 kg/dia. ²Suplemento fornecido na quantidade de 3 g/kg PC, PB = 25%, NDT = 60%, @ colocada 2,0 e ganho médio diário = 0,400 kg/dia.

Os valores permitem reforçar que a suplementação durante a estação seca entra na dieta repondo, prioritariamente, as deficiências de compostos nitrogenados, fornecendo 21,1 e 29,6% da PB consumida para os suplementos 1 e 3 g/kg do PC, respectivamente. Em relação ao NDT, apenas 3,7 e 15,7% foram fornecidos pelos suplementos 1 e 3 g/kg do PC, respectivamente. No entanto, deve-se ter em mente que os valores absolutos são meramente demonstrativos, uma vez que o sinergismo do sistema boi × pasto × suplemento é extremamente dinâmico, não sendo possível generalizar, com precisão, a quantidade exata de nutrientes fornecidos por cada componente da dieta.

No caso da suplementação proteica, por exemplo, obtêm-se efeitos indiretos como aumento da degradação da fração fibrosa, taxa de passagem, consumo e, consequentemente, aumento no desempenho. Portanto, de maneira coloquial têm-se, nesse caso, desempenho superior ao esperado com a soma das partes individuais (pasto mais suplemento), devido aos benefícios da suplementação estratégica, ou seja, 1 + 1 > 2. Assim, fica evidente a atuação do pasto como peça chave na obtenção das primeiras @ da recria, no período seco, assim como evidencia que o uso da suplementação de maneira racional permite aos produtores explorar amplamente o potencial da forragem.
**Período de águas: potencializando os ganhos na safra do pasto**

Ao retorno da estação das chuvas, com condições favoráveis ao crescimento de pasto, é fundamental explorar ao máximo o potencial de desempenho dos animais, aliado ao uso efetivo da forragem, que nesse momento apresenta boa qualidade com alta oferta. Assim, o produtor terá em torno de 210 dias para conseguir as 5@ restantes do segundo 7, e para que isso ocorra, os animais deverão apresentar um ganho de, aproximadamente, 715 g/animal/dia. Embora seja uma meta arrojada, é possível obter pastos de elevada qualidade em condições tropicais, com valores de PB entre 13,9 e 17,2% e digestibilidade da matéria seca (MS) entre 74,1 e 81,7% (Roth *et al*., 2017). No entanto, para que isso ocorra, é necessário que se pratique manejos refinados, com adubação e pastejo altamente eficientes. Neste momento, o pasto aparece de maneira mais efetiva em relação à ingestão de nutrientes dos animais, já que a suplementação não tem como finalidade direta corrigir deficiências marcantes, como no período seco, e sim deve usada para promover ajustes finos e/ou incrementar o ganho, sendo utilizada de maneira estratégica.

Uma simulação com as equações propostas pelo BR-CORTE (2010), agora utilizando suplementos comerciais para as águas (Figura 2), evidencia a importância dos pastos quanto ao fornecimento dos nutrientes ingeridos pelos animais. Suplementos de baixo consumo (1g/kg), nesse instante, promovem incremento no ganho em peso por proporcionarem pequenos ajustes em eventuais desbalanço entre nutrientes e, sobretudo, por veicularem aditivos e moduladores da fermentação ruminal, os quais irão incrementar a eficiência do animal. Pode-se inferir também que, os efeitos dos suplementos de consumo mais elevado (3 e 5 g/kg), se dá pela substituição da ingestão de nutrientes e, ainda, quando se têm pastos de elevada qualidade e oferta condizente, o ganho adicional será menor, pois a dieta como um todo não sofrerá grandes alterações.
Boi 777: qual é o papel da forragem neste sistema?

Figura 2 - Participação do pasto e suplementos no consumo total de matéria seca (MS), proteína bruta (PB) e nutrientes digestíveis totais (NDT) no período das águas.

Exigências calculadas a partir das equações propostas pelo BR-CORTE (2010). Peso inicial = 210 kg. ¹Suplemento fornecido na quantidade de 1 g/kg do peso corporal (PC), PB = 30%, NDT = 40%, @ colocada 5,0 e ganho médio diário = 0,714 kg/dia. ²Suplemento fornecido na quantidade de 3 g/kg PC, PB = 25%, NDT = 60%, @ colocada 5,0 e ganho médio diário = 0,714 kg/dia. ³Suplemento fornecido na quantidade de 5 g/kg PC PB = 20%, NDT = 65%, @ colocada 5,0 e ganho médio diário = 0,714 kg/dia

Evidenciando os efeitos em função do manejo da pastagem, foi desenvolvida uma série de trabalhos na FCA V/UNESP com intuito de elucidar a atuação da suplementação no desempenho de animais no período das águas, com três diferentes alturas de pastejo (15, 25 e 35 cm), em pastos de capim-Marandu. Nesses estudos, verificou-se que o desempenho individual dos animais se eleva à medida em que o pasto é manejado com alturas mais elevadas de dossel e menores taxas de lotação. O inverso é verdadeiro para o ganho por área, onde menores alturas promovem maior ganho por área. Contudo, ao se utilizar a suplementação, é possível conciliar ganho por área e ganho médio diário individual (Casagrande, 2010; Oliveira, 2014) (Tabela 2).

Na pressão de pastejo ótima, quando o ganho individual e ganho por área atingem valor máximo, Casagrande (2010) verificou ganhos de 718,4 g/dia e 689,0 kg/ha. Ao observar as variáveis de forma conjunta, a altura do dossel na qual a pressão de pastejo atingiu o nível ótimo, foi de 23 cm (Figura 3). Estudos semelhantes foram desenvolvidos na APTA/Colina, onde em alturas mais elevadas de dossel forrageiro também foi observado desempenho individual superior, porém com redução na taxa de lotação. Para alturas de 15 e 35 cm, o ganho foi de 0,698 e 1,02 kg/animal/dia, respectivamente, um incremento de 46,1% apenas manejando o pasto para proporcionar altura de dossel mais elevada (Costa, 2016).
Tabela 2 - Desempenho e taxa de lotação de novilhas e novilhos sob diferentes alturas de dossel em pastos de capim-Marandu e diferentes suplementos

<table>
<thead>
<tr>
<th>Variável</th>
<th>Altura, cm</th>
<th>Suplemento¹</th>
<th>Autor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Ganho médio diário, kg/dia</td>
<td>0,511ᵇ</td>
<td>0,608ᵃᵇ</td>
<td>0,713ᵃ</td>
</tr>
<tr>
<td>Taxa de lotação, UA/ha</td>
<td>5,8ᵃ</td>
<td>4,5ᵇ</td>
<td>3,4ᶜ</td>
</tr>
<tr>
<td>Ganho médio diário, kg/dia</td>
<td>0,695ᵇ</td>
<td>0,874ᵃ</td>
<td>0,954ᵃ</td>
</tr>
<tr>
<td>Taxa de lotação, UA/ha</td>
<td>6,6ᵃ</td>
<td>5,0ᵇ</td>
<td>4,1ᶜ</td>
</tr>
</tbody>
</table>

Médias seguidas de mesma letra na linha não diferem entre si pelo teste Tukey (P > 0,05). ¹SM = sal mineral; SPE = suplemento proteico-energéticos, valores médios. ²Novilhas Nelore em submetidas a três alturas e três suplementações. ³Novilhos Nelore em submetidas a três alturas e três suplementações.

Figura 3 - Relação entre ganho observado e ganho máximo estimado para o ganho médio diário (GMD) e ganho por área (GA) de novilhas recebendo suplemento proteico energético com consumo de 3 g/kg do peso corporal, em função da altura do dossel em pastagens de capim-Marandu, durante o período das águas. Adaptada de Casagrande (2010).

Outro fator a ser considerado, ao se implantar um programa de suplementação, é que o ganho adicional obtido, durante a recria, se mantém no confinamento, desde que os planos nutricionais sejam crescentes, permitindo abater animais com maior PC e peso de carcaça, ou mesmo obtendo redução no tempo de confinamento, quando os animais são abatidos com PC semelhante.
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(Tabela 3). Portanto, a escolha por potencializar os ganhos na recria, seja através da suplementação, manejo da pastagem ou ambos, deve fazer parte de uma estratégia macro.

A partir do exposto, para completar as $5@$ restantes do 7 referente a recria, reveste-se de importância adotar manejo adequado das pastagens, visando explorar ao máximo seu potencial. Neste período, a suplementação permite conciliar desempenho individual com ganho por área elevado, mantendo seus benefícios na fase seguinte, a terminação.

**Tabela 3 -** Desempenho e tempo de confinamento (dias) de animais oriundos de diferentes estratégias nutricionais na recria

<table>
<thead>
<tr>
<th>Suplementação</th>
<th>GMD, kg/dia</th>
<th>Tempo</th>
<th>PC inicial, kg</th>
<th>PC final, kg</th>
<th>Autor</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM¹ 1,230ª</td>
<td>169ª</td>
<td>288c</td>
<td>496ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 g/kg 1,250ª</td>
<td>151ª</td>
<td>301ª</td>
<td>490ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 g/kg 1,210ª</td>
<td>148ª</td>
<td>309ª</td>
<td>485ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 g/kg 1,180ª</td>
<td>143ª</td>
<td>320ª</td>
<td>488ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM 0,829ª</td>
<td>90,0ª</td>
<td>275ª</td>
<td>352ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 g/kg - E 0,866ª</td>
<td>65,0ª</td>
<td>294ª</td>
<td>357ª</td>
<td></td>
<td>Correia (2006)</td>
</tr>
<tr>
<td>3 g/kg - P 0,857ª</td>
<td>63,0ª</td>
<td>296ª</td>
<td>356ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasto 15 cm 0,823ª</td>
<td>94,0ª</td>
<td>273ª</td>
<td>355ª</td>
<td></td>
<td>Vieira (2011)</td>
</tr>
<tr>
<td>Pasto 25 cm 0,876ª</td>
<td>65,0ª</td>
<td>293ª</td>
<td>351ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasto 35 cm 0,863ª</td>
<td>58,0ª</td>
<td>300ª</td>
<td>353ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM 1,420ª</td>
<td>91,0ª</td>
<td>357ª</td>
<td>486ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 g/kg 1,210ª</td>
<td>79,0ª</td>
<td>385ª</td>
<td>482ª</td>
<td></td>
<td>Sampaio <em>et al.</em> (2017)</td>
</tr>
<tr>
<td>3 g/kg 1,150ª</td>
<td>59,0ª</td>
<td>419ª</td>
<td>486ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM 0,954ª</td>
<td>143ª</td>
<td>370ª</td>
<td>504ª</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 g/kg 0,902ª</td>
<td>135ª</td>
<td>393ª</td>
<td>513ª</td>
<td></td>
<td>Roth <em>et al.</em> (2017)</td>
</tr>
<tr>
<td>3 g/kg 0,870ª</td>
<td>130ª</td>
<td>404ª</td>
<td>516ª</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Médias seguidas de mesma letra na linha não diferem entre si pelo teste Tukey ($P > 0,05$). PC = peso corporal. SM = sal mineral. E = suplemento energético. P = suplemento proteico.
A importância do pasto na terminação do Boi 777

A terminação no Conceito Boi 777 representa aproximadamente 16% da vida do animal, ou seja, o animal deve ganhar as mesmas 7@ das outras duas fases (cria e recria), porém, em um período mais curto. Para isso, devem ser utilizadas estratégias de alimentação que possibilitem alta taxa de ganho, importante para produzir uma carcaça com o mínimo de acabamento desejado. O padrão de crescimento dos animais da terminação é diferente das fases anteriores. Quanto mais próximo da maturidade e mais pesado o animal, menor a deposição de proteína, com aumento proporcional na deposição de gordura. Como é de conhecimento geral, essa mudança no padrão de deposição de tecido altera a exigência dos animais, pois eles precisam de mais energia na dieta para depositar mais gordura em relação a proteína. Com isso, essa é a fase mais complexa com relação ao uso isolado do pasto, pois o mesmo não consegue fornecer a quantidade suficiente de energia para atender a alta exigência dos animais.

Normalmente, quando se almeja essa alta taxa de ganho é utilizado o confinamento, no qual os animais são retirados do pasto de recria para baias e recebem dieta total balanceada. Uma alternativa que vem sendo explorada atualmente é a alta suplementação dos animais no pasto (terminação intensiva a pasto), sendo o concentrado fornecido em cochos, enquanto o volumoso é proveniente do próprio pasto. Cabendo ao animal selecionar e regular seu consumo, diferente do confinamento convencional, no qual a ração total é fornecida misturada. Algumas vantagens desta estratégia são: não necessita estocar volumoso, redução de custo (infraestrutura do confinamento convencional é mais cara), possibilidade de ser realizada o ano todo, fornecimento de um trato no dia (o animal regula o consumo de suplemento), além de auxílio no bem-estar do animal. Porém, é necessário reservar área para esta prática, com forragem suficiente até o final da terminação (planejamento dos piquetes).

A necessidade de alta taxa de ganho pode ser observada quando analisamos os dados de experimento conduzido na APTA/Colina (Custódio et al., 2016), no qual animais Nelore, não castrados, com PC inicial de 480 kg, foram terminados por 89 dias a pasto no período da seca. Sendo comparadas a suplementação de 5 g/kg de PC com 20 g/kg de PC. Animais recebendo 20 g/kg apresentaram maior ganho médio diário (1,505 kg/dia) quando comparados a 5 g/kg (0,534 kg/dia), acarretando em 77 kg a mais de carcaça e 4,9% a mais de rendimento de carcaça. Além disso, a espessura de gordura dos animais que receberam 5 g/kg foi de 1,8 mm, enquanto dos animais que receberam 20 g/kg foi de 3,6
mm. Estes resultados comprovam a necessidade de um aporte energético maior na dieta, para que o animal atinja acabamento para ser terminado no tempo proposto, sendo esses resultados ainda mais discrepantes se comparados com o fornecimento de sal mineral.

A recomendação para sistemas de confinamento no pasto é que os lotes não sejam maiores que 150 cabeças, havendo maior uniformidade e minimizando problemas de competição e diferença de consumo. Outro ponto importante é a adaptação, principalmente quando se fornece sal mineral nas fases anteriores. Esta adaptação deve ser encarada da mesma forma que o confinamento convencional, podendo ser feita de várias formas, por exemplo, começando com 5 g/kg do PC, e ir aumentando gradativamente, até atingir 20 g/kg do PC, após 15 a 20 dias. Deve se atentar, também, para a composição do concentrado, que deve conter núcleo composto por minerais, vitaminas e aditivos que auxiliem no controle de distúrbios metabólicos.

E qual a importância do pasto na terminação do Boi 777? Ao contrário das fases anteriores, nesta, grande parte do consumo do animal é proveniente do concentrado, sendo, portanto, a principal fonte de nutrientes da dieta. Em média, apenas 15% a 20% do consumo diário do animal será de pasto. Além disso, menos de 10% das exigências de PB e NDT serão supridos pelo pasto. Porém, o pasto não deve ser deixado de lado, muito pelo contrário, seu correto manejo é importantíssimo para o sucesso desse sistema, pois o mesmo será a única fonte de volumoso para o animal, auxiliando na motilidade ruminal, ruminação e controle de pH, consequentemente, diminuindo riscos de acidose. Portanto, é preciso entender qual pasto iremos trabalhar neste sistema, pois a terminação intensiva a pasto pode ser feita em todos os períodos do ano e é sabido que a forragem muda sua composição e produtividade.

Com relação a oferta de forragem, foram realizados experimentos usando alta suplementação a pasto na terminação, avaliando alta e baixa oferta. Vellini (2014) comparou baixa (2,5 kg de MS/kg de PC) e alta oferta (4,5 kg de MS/kg de PC) de pastos de capim Marandu. Os animais mantidos na maior oferta de forragem aumentaram a eficiência de utilização do concentrado. Foram necessários 15 kg a menos de suplemento para a produção da mesma @ de carcaça. Já Mota (2015) avaliou pastos de capim Marandu com ofertas de 1,3 (baixa oferta) e 2,9 (alta oferta) kg MS/kg de PC. A autora não encontrou diferença entre as duas ofertas no desempenho e características de carcaça. A diferença entre os estudos é que no trabalho de Vellini (2014), o pasto no tratamento de baixa oferta tornou-se muito escasso na fase final, o que não aconteceu no trabalho de Mota (2015). Dessa forma, é importante destacar...
que o principal ponto é haver forragem disponível para o animal durante todo o período de terminação.

Com os dados apresentados e discutidos acima, fica clara a importância do pasto no sistema de terminação do Boi 777 (último 7), sendo primordial o entendimento de qual época do ano está sendo realizada esta fase, geralmente no período seco. Na terminação a pasto, é primordial que os animais recebam altos níveis de suplementação para suprir os nutrientes limitantes da dieta basal (pasto) e atender suas exigências de energia para serem abatidos com peso de carcaça e acabamento adequados. Esta suplementação é variável, dependendo de diversos fatores como preço da @, preço do suplemento, qualidade e quantidade do pasto e objetivo almejado pelo produtor. Seguido todos os passos, com metas traçadas e o manejo adequado, o sucesso da operação estará próximo de ser alcançado.

**Sumário**

Para o sucesso do Conceito Boi 777, deve ser dada a correta importância, primeiramente, para a dieta basal. A suplementação deve ser encarada como estratégia alimentar para suprir as deficiências nutricionais do pasto em determinada exigência de ganho de peso. A alta suplementação no pasto no período da terminação deve ser encarada como uma dieta de confinamento convencional, no qual o animal necessita do volumoso que, neste caso, é o próprio pasto. Em resumo, suplemento não é, e nunca poderá ser encarado, como concorrente do pasto. Deverá ser sempre o seu maior aliado, para alcançar as metas produtivas e econômicas.

Por fim, o Conceito Boi 777 foi criado para que o produtor tenha metas estipuladas e tempo proposto para executá-las (planejamento), fazendo com que a pecuária se torne mais competitiva e profissional, podendo assim competir melhor com outras práticas. Os trabalhos desenvolvidos são caminhos que podem ser seguidos para alcançar esse objetivo, cabendo ao produtor escolher o melhor, uma vez que o caminho irá variar de fazenda para fazenda. O importante é ter em mente que tudo deve ser planejado, medido e executado para alcançar o sucesso da produção.
Referências


Mota, V. A. C. *Efeito de diferentes ofertas de foragem na terminação de bovinos nelore recebendo alta suplementação recriados com diferentes taxas de ganho*. 2015. 68f. Dissertação (Mestrado em Zootecnia) - Faculdade de Ciências Agrárias e Veterinária, Jaboticabal, 2015.


USE AND DISUSE OF FORAGE IN FEEDLOT FINISHING DIETS

Daniel, J. L. P1.

Introduction

Fiber (level and source) impacts animal performance and feedyard profit. Therefore, roughages are typically included at minimal concentrations in high-concentrate finishing feedlot diets to reduce the incidence of digestive disorders and to improve animal performance. Compared with all-concentrate diets (without roughage), a certain inclusion of physically effective fiber (peNDF) should increase dry matter (DM) and net energy for gain (NEg) intake and thus, average daily gain (ADG). As roughage DM is typically cheaper than grain DM, the ration cost is often lower when the diet contains a higher proportion of roughage (least costly ration, $/kg of DM). However, since NEg cost is frequently lower for grains than roughages, high-grain diets commonly lead to least costly weight gain ($/@).

In feedlots, diets rich in energy (and other nutrients) are preferred for numerous reasons. First, when compared with high-forage diets, high-grain diets are more digestible and result in lower heat increment, less CH4/DM intake and higher feed efficiency (gain:feed, G:F), therefore providing NEg at a lower cost. Second, due to the higher ADG, the energy partitioned for maintenance as a proportion of energy intake along the life cycle is lower for cattle receiving high-grain diets. Third, the faster rate of growth reduces the period that cattle are fed, and in turn, the cost of interest on the capital invested in animals and other fixed costs. Fourth, fat deposition and marbling is most readily achieved at lower carcass weights by feeding high concentrate diets. Fifth, beyond the lower digestibility, roughages are less consistent in terms of chemical composition and more bulky, so grains and high-grain diets are more readily transported, stored, processed and handled (lower operational cost), and result in higher carcass dressing percentage and less indigestible waste (lost to the environment) than forage-based diets. Finally, compared with grains obtained from the marketing, forage production inside the farm requires more labor and arable lands. Although ruminant diets with higher roughage levels has been argued more environmentally sustainable, a lower ADG associated

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with higher DM intake (lower feed efficiency), a longer feeding period, a higher percentage of NE partitioned to maintenance along the life cycle (due to the lower ADG), and a higher methane production per kilogram of meat could at least partially offset the advantages of ‘high-forage’ systems.

In brief, the amount of roughage that is fed represents a balance between the benefits noted with feeding minimal levels of peNDF (increased DM intake, chewing, ruminal ‘mat’ formation and ruminal pH, and reduced bloat, liver abscess and lameness incidences) versus the advantages noted with feeding lower fiber levels (outlined above). Therefore, ideal dietary concentration of dietary roughage can differ with source of roughage, grain processing, and the specific response criterion chosen (target).

Roughage Sources and Levels in Brazilian Feedlots

Generally, nutritionists should consider four main factors when selecting among roughage sources. First comes roughage availability, second is its final cost relative to its nutritive value, third is its “roughage” value (level of peNDF), and fourth is its capacity to mix with other diet components and reduce particle segregation (Owens, 2008).

Currently in Brazil, feedlot operations are moving nearer the agricultural regions, what makes concentrate (grains and their byproducts) cheaper. In a first survey with Brazilian nutritionists, Millen et al. (2009) reported the average content of concentrates in the finishing diet was 71.2% compared to 79.0% in the second survey (Oliveira and Millen, 2014) and 79.4% in the more recent scenario (Pinto and Millen, 2016). So, concentrate proportion keeps going up in Brazilian feedlots. Interestingly, while roughage level is decreasing, grain processing is enhancing, as high-moisture and steam-flaked corn arose in the last survey. Corn silage is by far the primary roughage source in finishing diets, but other roughage sources has been declared in use [e.g. sugarcane sources (bagasse, silage), sorghum silage, grass silage] (Oliveira and Millen, 2014; Pinto and Millen, 2016). For purposes of comparison, in US feedlots, corn silage and corn stalks were recently reported as the primary roughage sources in finishing diets and, in most cases, comprised from 8 to 10% of diet DM (Samuelson et al., 2016).

By the way, in times of high grain prices (comparatively to meat price), three major nutritional strategies might surface in feedlots: i) partially replace grains with byproducts (e.g. citrus pulp, distillers grains, soybean hulls, corn
gluten feed); ii) enhance grain processing to increase grain digestibility (e.g. ensiling high moisture grains, steam flaking), so the final cost of grain NEg will decrease, and iii) produce ‘high-quality’ forages (e.g., corn silage with a high grain proportion), consequently the diet may contain a higher level of that ‘high-quality’ forage, without compromise the animal performance. Combining those strategies shall helping feedyards thriving under high grain prices.

**Fiber, Ruminal Acidosis and Animal Performance**

Ruminal acidosis (sub-acute or acute) is the excessive accumulation of acids in the rumen (mainly volatile fatty acids), which occurs when the rate of acids production exceeds the rate of acids removal (absorption + passage). Experimentally, ruminal acidosis has been characterized when the pH drops below a certain level (e.g. < 5.8) during a certain time period (e.g. > 3 h/d) (Owens *et al*., 1998; Beauchemin *et al*., 2001; Castillo-Lopez *et al*., 2014). This digestive disturb is associated with depressed and variable DMI, alteration of rumen microbiota, decreased fiber digestibility, decreased rumen motility, bloat, damage on rumen epithelium, decreased VFA absorption, rumenitis, liver abscess and lameness (NRC, 2016). Therefore, roughages are included in high-concentrate finishing feedlot diets to reduce the risk of metabolic disorders and improve animal performance and feedlot profit.

When more roughage is used, the diet will contain more NDF and, consequently, less nonfiber carbohydrates (NFC), which is mainly comprised of starch. Hence, changes in NDF always are associated with an opposite change in NFC concentration. The NDF fraction is slowly digested than NFC. Hence, the major effect of including roughage in diet is decrease the rate of carbohydrates digestion, diminishing the rate of acids production in the rumen. In addition, the physical effectiveness of roughage sources (peNDF) is capable to stimulate chewing and saliva secretion, rumen mat structuring, rumen motility and passage rate, what increase buffer influx and removal of acids. Furthermore, increasing roughage supply tends to slower the eating rate (kg DM/min) and, due to the higher passage rate, may shift starch digestion from rumen to intestines, diminishing the rate of acid production in the rumen (Yang and Beauchemin, 2006). Beyond including a minimal proportion of peNDF in diet, other management strategies such as diet adaptation and feedbunk management are imperative to prevent ruminal acidosis (Table 1).
Table 1 - Factors affecting rumen pH in feedlot cattle (NRC, 2016)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Increased pH</th>
<th>Decreased pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage</td>
<td>Greater proportion, longer particles</td>
<td>Lower proportion, shorter particles</td>
</tr>
<tr>
<td>Grain</td>
<td>Corn, sorghum</td>
<td>Barley, wheat</td>
</tr>
<tr>
<td>Grain processing</td>
<td>Whole, coarsely rolled</td>
<td>Finely ground, stem flaked, flat flakes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>decreasing bulk density, high moisture</td>
</tr>
<tr>
<td>Feed additives</td>
<td>Ionophores, buffers</td>
<td></td>
</tr>
<tr>
<td>F e e d management</td>
<td>Consistent daily allocation and delivery time</td>
<td>Inconstant daily allocation and delivery time</td>
</tr>
<tr>
<td>F e e d i n g frequency</td>
<td>More than once daily</td>
<td>Once daily</td>
</tr>
<tr>
<td>Duration of feeding</td>
<td>Shorter time on feed</td>
<td>Longer time on feed</td>
</tr>
<tr>
<td>D i e t a r y transition</td>
<td>Gradual dietary transition, longer adaptation to diets</td>
<td>Abrupt dietary transition, short adaptation to diet</td>
</tr>
</tbody>
</table>

Although the last two editions of the Nutrient Requirements of Beef Cattle (NRC, 1996 and 2016) reported a table indicating the requirements of physically effective NDF (Table 2), it has received less attention in practice. In US and Canada, commercial feedlot finishing diets are often below those recommendations (Vasconcelos and Galyean, 2007; Koenig and Beauchemin, 2011; Samuelson et al., 2016). In fact, the current (8th) edition of the Beef Cattle Nutrient Requirement Model (NRC, 2016) recognizes that physically effective NDF described as the percent of the NDF remaining on a 1.18 mm screen after dry sieving (peNDF >1.18) is limited as a sole predictor of ruminal pH, particularly for feedlot cattle diets, since this concept does not account for the fermentability of diet or clearance of VFA from the rumen. Owens et al. (1997) reported the effects of peNDF >1.18 on DMI and ME of grain are neither large nor consistent. Actually, peNDF >1.18 accounts for considerably less of the variation in ruminal pH for beef cattle (Sarhan and Beauchemin, 2015). Interestingly, a recent data-analysis showed that an equation based on the dietary level of forage was more precise to predict ruminal pH than peNDF >1.18 for beef cattle (NRC, 2016), suggesting that peNDF based on animal responses (i.e. chewing) measured by bioassays might be more realistic than peNDF >1.18 (measured with a screen), especially when the goal is replace traditional with non-traditional roughage sources (Goulart, 2010).
**Table 2 - Estimated peNDF\textsubscript{>1.18} requirements (1.18 mm screen) (from NRC, 1996, 2016)**

<table>
<thead>
<tr>
<th>Diet Type</th>
<th>Minimum peNDF\textsubscript{&gt;1.18} required, % of DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-concentrate diet to maximize feed efficiency, fed mixed ration, good feed bunk management, and ionophores</td>
<td>5 to 8</td>
</tr>
<tr>
<td>Fed mixed ration, variable feed bunk management, or no ionophore</td>
<td>20</td>
</tr>
<tr>
<td>High-concentrate to maximize NFC use and microbial protein yield\textsuperscript{a}</td>
<td>20</td>
</tr>
</tbody>
</table>

\textsuperscript{a}To keep ruminal pH above 6.2 to maximize cell-wall digestion and microbial protein yield.

In the past version of the NRC (1996), the empirical level of solution (Level 1) included a discount to adjust microbial protein yield for diets with low peNDF\textsubscript{>1.18} (<20% of peNDF\textsubscript{>1.18}). The validity of predicting microbial protein synthesis by NRC (1996) has neither been extensively assessed experimentally nor validated with independent data. Furthermore, the peNDF\textsubscript{>1.18} adjustment was based on limited data, and measures of peNDF\textsubscript{>1.18} for diets are limited (NRC, 2016). Then, the committee of the current (8th) edition abandoned that adjustment based on peNDF\textsubscript{>1.18} and, for the empirical level of solution, adopted two new equations to predict the microbial protein synthesis based on the intake of TDN (diets with <3.9% of ether extract) or fat-free TDN (≥3.9% of ether extract) (Galyean and Tedeschi, 2014; NRC, 2016).

In past years, several reviews have been conducted to check the effects of roughage/fiber level on the performance of finishing feedlot cattle (Galyean and Defoor, 2003; Arelovich \textit{et al.}, 2008; Galyean and Hubbert, 2014). In brief, the reviews indicated that increasing roughage NDF levels in high-concentrate finishing feedlot diets linearly decreased feed efficiency and increased DM and NEg intake (Figure 1).

![Figure 1 - Influence of roughage NDF level on net energy for gain (NEg) intake (from Defoor \textit{et al.}, 2002).](image-url)
Recently, Swanson et al. (2017) reported a quadratic trend for DM intake (DMI) and linear decay in ADG and feed efficiency by increasing forage NDF in finishing diets. Varying forage NDF level from 3.8% to 11.4% had a minimal influence on feed intake, but including more than 11.4% of forage NDF induced a largest decrease in DMI (Table 3).

Table 3 - Influence of forage level on eating behavior and performance of finishing steers fed dry-rolled corn-based diets (Swanson et al., 2017)

<table>
<thead>
<tr>
<th>Item</th>
<th>3.8%</th>
<th>7.6%</th>
<th>11.4%</th>
<th>15.2%</th>
<th>(P^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal bolts, n/d</td>
<td>8.35</td>
<td>8.56</td>
<td>8.45</td>
<td>8.96</td>
<td>L</td>
</tr>
<tr>
<td>Eating rate, g/min</td>
<td>124</td>
<td>142</td>
<td>114</td>
<td>100</td>
<td>Q</td>
</tr>
<tr>
<td>DMI per meal, kg</td>
<td>1.44</td>
<td>1.40</td>
<td>1.37</td>
<td>1.15</td>
<td>Q</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>11.6</td>
<td>11.5</td>
<td>11.2</td>
<td>9.8</td>
<td>Q</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>2.31</td>
<td>2.18</td>
<td>2.09</td>
<td>1.81</td>
<td>L</td>
</tr>
<tr>
<td>G:F</td>
<td>0.197</td>
<td>0.187</td>
<td>0.184</td>
<td>0.178</td>
<td>L</td>
</tr>
</tbody>
</table>

\(^1\)Forage NDF: \(\frac{1}{2}\) from bromegrass hay + \(\frac{1}{2}\) from corn silage.  
\(^2\)L: linear effect, Q: quadratic effect of forage NDF level.

In diets formulated with sugarcane fiber sources (fresh chopped, silage, bagasse) the optimum level of roughage NDF would be expectedly lower, due to the higher physical effectiveness of sugarcane NDF (please see the next topic “Exchanging roughage sources”). Santos et al. (2013) carried-out a meta-analysis with data from finishing trials where different levels of sugarcane fiber sources (bagasse and silage) for fed to Nellore cattle (Figures 2, 3 and 4). As reported in US meta-analysis, feed efficiency was linearly decreased with forage NDF levels. However, DMI and ADG showed quadratic trends, with maximum points at 13.4% and 12.0%, respectively. The authors declaimed the quadratic trend for DMI might have occurred because of the lower nutritive value of sugarcane fiber, compared with traditional forage sources used in US (e.g. corn silage, alfalfa hay).
Figure 2 - Effect of sugarcane fiber level on dry matter intake (as percentage of body weight) in finishing Nellore cattle. \( y = -0.001x^2 + 0.0268x + 1.986 \), \( R^2 = 0.88 \), maximum point (vertex) = 13.4\% of forage NDF (from Santos et al., 2013).

Figure 3 - Effect of sugarcane fiber level on average daily gain in finishing Nellore cattle. \( y = -0.0009x^2 + 0.0218x + 1.398 \), \( R^2 = 0.86 \), maximum point (vertex) = 12.0\% of forage NDF (from Santos et al., 2013).

Figure 4 - Effect of sugarcane fiber level on feed efficiency (G:F) in finishing Nellore cattle. \( y = -0.0006x + 0.152 \), \( R^2 = 0.91 \) (from Santos et al., 2013).
Exchanging Roughage Sources

Roughage or fiber requirement has been expressed in several ways. Initially, roughage level was the first attempt to achieve fiber requirements. However, because of large differences in NDF content among roughage sources, the same level of forage (on a DM basis) may lead to different scenarios. For instance, it can be easily noticed by exchanging corn silage with sugarcane bagasse (extreme example!).

Afterwards, forage NDF appeared as a better measure of ‘roughage value’, and in fact, it has been successfully adopted for exchanging traditional roughage sources (Galyean and Defoor, 2003). However, roughage sources may differ in particle size, and in turn, in its ‘roughage value’ (physical effectiveness). Hence, Mertens (1997) proposed a laboratorial method to predict physical effectiveness based on the percent of the NDF remaining on a 1.18 mm screen after dry sieving. Nonetheless, several studies have concluded that altering forage particle size may provide limited benefits in improving finishing performance (Tables 4, 5 and 6). Furthermore, it was clearly demonstrated by Campos (2015) that coarser forage processing encouraged sorting against longer particles in feedbunk, offsetting the expected higher physical effectiveness of long particles (Table 6). Therefore, other factors, such as ease of handling and processing cost, should be considered when processing forages.

Table 4 - Influence of forage level and particle size on the performance of steers fed steam-flaked corn based diets (Calderon-Cortes and Zinn, 1996)

<table>
<thead>
<tr>
<th>Forage level</th>
<th>Coarseness¹</th>
<th>16%</th>
<th>8%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5 cm</td>
<td>7.6 cm</td>
<td>2.5 cm</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 cm</td>
<td>7.00</td>
<td>7.28</td>
<td>6.94</td>
</tr>
<tr>
<td>7.6 cm</td>
<td>1.20b</td>
<td>1.15b</td>
<td>1.41a</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 cm</td>
<td>6.13x</td>
<td>6.49x</td>
<td>4.94y</td>
</tr>
<tr>
<td>7.6 cm</td>
<td>5.84x</td>
<td>5.93x</td>
<td>5.61y</td>
</tr>
<tr>
<td>DMI/ADG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5 cm</td>
<td>9.2y</td>
<td>8.1y</td>
<td>11.5^</td>
</tr>
<tr>
<td>7.6 cm</td>
<td>10.5^</td>
<td>11.5^</td>
<td></td>
</tr>
</tbody>
</table>

¹Sudangrass hay was ground to pass through a screen with a diameter of 2.5 or 7.6 cm.

a,b Forage level effect (P < 0.05); x,y Forage level effect (P < 0.10).
Table 5 - Effect of particle size on the performance of finishing steers (Shain *et al*., 1999)

<table>
<thead>
<tr>
<th>Screen size</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.95 cm</td>
<td>7.6 cm</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>11.7</td>
<td>11.8</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>1.70</td>
<td>1.69</td>
</tr>
<tr>
<td>G:F</td>
<td>0.146</td>
<td>0.143</td>
</tr>
<tr>
<td>Liver abscess score (0-4)</td>
<td>0.09</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Trial 1: Average results of dry-rolled corn based diets containing 10% of alfalfa hay or 5.2% of wheat straw. Trial 2: Dry-rolled corn based diet containing 10% of alfalfa hay.

Table 6 - Influence of sugarcane silage particle size on performance of finishing Nellore bulls (Campos, 2015)

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean particle size</th>
<th>P'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.1</td>
<td>11.0</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>10.8</td>
<td>9.91</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>1.56</td>
<td>1.44</td>
</tr>
<tr>
<td>G:F</td>
<td>0.145</td>
<td>0.145</td>
</tr>
<tr>
<td>DM digestibility, %</td>
<td>53.6</td>
<td>51.8</td>
</tr>
<tr>
<td>Chewing, min/d</td>
<td>543</td>
<td>615</td>
</tr>
<tr>
<td>Physical effectiveness factor (pef)</td>
<td>1.08</td>
<td>1.20</td>
</tr>
</tbody>
</table>

L: linear effect, Q: quadratic effect of mean particle size.

The nature of NDF may differ among roughage sources. Peculiarities of chemical composition, cross-linkage of cell wall polymers, and organization of plant tissues are possibly responsible for observed differences in digestibility, fragility (communion rate) and physical effectiveness (Wilson, 1993; Sá Neto *et al*., 2014). Investigating levels and sources of roughage (alfalfa hay or cottonseed hulls), Bartle *et al*. (1994) reported interactions between roughage level and source on growing performance of finishing cattle, perhaps caused by dissimilarities in NDF nature. Increasing alfalfa hay from 10% to 20% did not alter the ADG, whereas increasing the level of cottonseed hulls from 10% to 30% depressed the ADG linearly.

In an effort to define a more realistic measure of fiber effectiveness, Armentano and Pereira (1997) proposed a method to determine ‘effectiveness factors’ based on animal responses (bioassay) that integrate the physical and nonphysical characteristics of dietary carbohydrate. Since chewing (eating + ruminating) is strongly related to forage content and forage particle size, chewing time was choose as an excellent response variable to peNDF. Using the
bioassay proposed by Armentano and Pereira (1997), Goulart (2010) determined the physical effectiveness factor (pef) of forage and non-forage fiber sources in Nellore steers. As expected, the author reported that sugarcane NDF (i.e., fresh chopped or bagasse) had a pef (based on animal responses) at least 20% higher than that of corn silage (a traditional forage source). Although corn silage had longer particles, sugarcane fiber sources were much more effective to promote chewing and ruminal ‘mat’ consistence and increase ruminal pH. In the same trial, the author compared the pef obtained from animal responses with pef$_{>1.18}$ measured with a 1.18 mm screen (laboratorial method). Remarkably, pef and pef$_{>1.18}$ were no positively correlated. Actually, plotting the pef$_{>1.18}$ versus pef obtained by chewing per DMI (min/kg) showed a significant negative slope! (Table 7). Then, pef and pef$_{>1.18}$ might lead to distinct scenarios, especially if traditional forages are exchanged by non-traditional roughage sources (Table 8).

**Table 7** - Pearson correlation among physical effectiveness factors measured by animal responses (bioassay) or a 1.18 mm screen (pef$_{>1.18}$) (Goulart, 2010)

<table>
<thead>
<tr>
<th>pef$_{&gt;1.18}$</th>
<th>pef$_{(chewing, min/d)}$</th>
<th>pef$_{(chewing, min/kg DM)}$</th>
<th>pef$_{(ruminal 'mat')}$</th>
<th>ef$_{(ruminal pH)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>r = 0.18</td>
<td>r = -0.38</td>
<td>r = 0.13</td>
<td>r = -0.14</td>
<td></td>
</tr>
<tr>
<td>(P=0.28)</td>
<td>(P=0.02)</td>
<td>(P=0.44)</td>
<td>(P=0.40)</td>
<td></td>
</tr>
</tbody>
</table>
### Table 8 - Deviation between $^1\text{peNDF}_{>1.18}$ and $^2\text{peNDF}$ across selected forage sources

<table>
<thead>
<tr>
<th>Source</th>
<th>NDF, %DM</th>
<th>$^1\text{pef}_{&gt;1.18}$ (screen)</th>
<th>$^2\text{peNDF}_{&gt;1.18}$, %DM</th>
<th>Level of forage to meet 8% of $^2\text{peNDF}_{&gt;1.18}$</th>
<th>Level of forage to meet 10% of $^2\text{peNDF}_{&gt;1.18}$</th>
<th>Level of forage to meet 12% of $^2\text{peNDF}_{&gt;1.18}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>50</td>
<td>0.81(^1)</td>
<td>40.5</td>
<td>19.8</td>
<td>24.7</td>
<td>29.6</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>45</td>
<td>0.92(^1)</td>
<td>41.4</td>
<td>19.3</td>
<td>24.2</td>
<td>29.0</td>
</tr>
<tr>
<td>Bermudagrass hay</td>
<td>67</td>
<td>0.98(^1)</td>
<td>65.7</td>
<td>12.2</td>
<td>15.2</td>
<td>18.3</td>
</tr>
<tr>
<td>Sugarcane silage</td>
<td>60</td>
<td>0.60(^1)</td>
<td>36.0</td>
<td>22.2</td>
<td>27.8</td>
<td>33.3</td>
</tr>
<tr>
<td>Sugarcane bagasse</td>
<td>82</td>
<td>0.59(^1)</td>
<td>48.4</td>
<td>16.5</td>
<td>20.7</td>
<td>24.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>NDF, %DM</th>
<th>$^1\text{pef}$ (animal)</th>
<th>$^2\text{peNDF}$, %DM</th>
<th>Level of forage to meet 8% of $^2\text{peNDF}$</th>
<th>Level of forage to meet 10% of $^2\text{peNDF}$</th>
<th>Level of forage to meet 12% of $^2\text{peNDF}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td>50</td>
<td>1.00(^1)</td>
<td>50.0</td>
<td>16.0</td>
<td>20.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>45</td>
<td>1.00(^1)</td>
<td>45.0</td>
<td>17.8</td>
<td>22.2</td>
<td>26.7</td>
</tr>
<tr>
<td>Bermudagrass hay</td>
<td>67</td>
<td>1.00(^1)</td>
<td>67.0</td>
<td>11.9</td>
<td>14.9</td>
<td>17.9</td>
</tr>
<tr>
<td>Sugarcane silage</td>
<td>60</td>
<td>1.20(^1)</td>
<td>72.0</td>
<td>11.1</td>
<td>13.9</td>
<td>16.7</td>
</tr>
<tr>
<td>Sugarcane bagasse</td>
<td>82</td>
<td>1.20(^1)</td>
<td>98.4</td>
<td>8.2</td>
<td>10.2</td>
<td>12.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th></th>
<th>Differences between $^1\text{peNDF}_{&gt;1.18}$ and $^2\text{peNDF}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage</td>
<td></td>
<td>+23%</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td></td>
<td>+9%</td>
</tr>
<tr>
<td>Bermudagrass hay</td>
<td></td>
<td>+2%</td>
</tr>
<tr>
<td>Sugarcane silage</td>
<td></td>
<td>+100%</td>
</tr>
<tr>
<td>Sugarcane bagasse</td>
<td></td>
<td>+103%</td>
</tr>
</tbody>
</table>

$^1\text{peNDF}_{>1.18} = \text{NDF} \times \text{pef}_{>1.18}$ (based on a 1.18 mm screen). $^2\text{peNDF} = \text{NDF} \times \text{pef}$ (based on animal responses). \(^3\text{NRC (2016)}; \(^4\text{Campos (2015)}; \(^5\text{Goulart (2010).}$
Based on the studies aforementioned, and respecting a minimal length of particles at forage harvesting or chopping (e.g. >10 mm), the roughage sources might be exchanged on a pHNDF basis (determined by bioassay) rather than on a NDF or pHNDF$_{>1.18}$ basis.

**Fiber Vs. Grain Processing and By-Products**

Grain processing and byproducts are claimed to alter the ideal level of roughage in high-concentrate finishing diets. Gill *et al.* (1981) evaluated five roughage levels (8%, 12%, 16%, 20%, and 24% of DM) with three corn processing forms [high moisture corn (HMC), stem flaked corn (SFC) or a 50:50 mixture of HMC and SFC). Roughage source was a mixture of 1/3 ground alfalfa hay and 2/3 corn silage (DM basis). For the corn silage, only the forage fraction (stalks, leaves, husks, and cobs) was assumed as roughage. Considering the ADG, optimal roughage levels were: 8% for SFC, 12% for the 50:50 mixture, and 16% for HMC, whereas for feed efficiency, optimal roughage levels were: 8% for SFC and 50:50 mixture and 16% for HMC. Stock *et al.* (1990) compared diets based on HMC or dry-rolled grain sorghum with 0%, 3%, 6% or 9% of roughage. Roughage was a 50:50 mixture of corn silage and alfalfa hay. Cattle fed HMC had lower DMI and were more efficient than cattle fed dry-rolled grain sorghum. There were no interactions between grain and roughage sources.

Caetano *et al.* (2015) appraised the effects of various levels of NDF from sugarcane bagasse on the performance of Nellore cattle fed flint corn diets containing either dry ground corn (DGC) or HMC. There was a quadratic effect of bagasse NDF on ADG, with optimal concentrations of bagasse NDF at 13.3%. An interaction was observed between corn processing and roughage NDF level for DMI, with peak DMI occurring at 11.3% and 13.7% of NDF from sugarcane bagasse for DGC and HMC, respectively (Figure 5). Cattle fed HMC had 13.9% greater feed efficiency compared with those fed DGC. An interaction between processing and bagasse level was also observed for fecal starch concentration. For bulls fed DGC, fecal starch linearly decreased as concentration of bagasse NDF increased, whereas fecal starch was always low in bulls fed HMC. Consistently with other trials (Silva *et al.*, 2007; Henrique *et al.* 2007; Silva, 2016), HMC greatly depressed DMI. Although, the higher ruminal degradability of HMC may have increased the risk of ruminal acidosis, the intake of metabolizable energy was lower in bulls fed HMC instead of DGC.
(Caetano et al., 2015), which might have been regulated by the hepatic portal flux of propionate (Allen et al., 2009), perhaps independent of acidosis. The increased anaplerosis of the tricarboxylic acid cycle in hepatocytes caused by higher propionic acid absorption has been associated with decreased meal size, DMI and metabolizable energy intake in ruminants (Gualdrón-Duarte and Allen, 2017). Partially replacing HMC (e.g. 1/3) with dry-ground corn or grain byproducts has been used in practical conditions to alleviate the DMI depression and improve NEg intake.

![Figure 5](image_url)

**Figure 5** - Influence of grain processing [dry finely ground corn (FGC) or high moisture corn (HMC)] and level of sugarcane silage NDF on dry matter intake (DMI) and fecal starch in Nellore bulls (from Caetano et al., 2015).

Melo (2015) and Sitta (2016) evaluated if the processing method (DGC or SFC) of corn with flint endosperm would interacts with NDF levels from sugarcane bagasse and corn silage fed to Nellore bulls (Tables 9 and 10, respectively). In both trials, SFC increased starch digestibility (less fecal starch), feed efficiency (G:F), hot carcass weight and backfat thickness. Interesting, DMI linearly increased in bulls fed corn silage, whereas in diets containing sugarcane bagasse, DMI followed a quadratic trend, with maximum at 11.3% of bagasse NDF. The level of roughage NDF linearly increased ADG in diets with corn silage but not in diets with sugarcane bagasse. In both trials (sugarcane bagasse and corn silage), there was no interaction between corn processing (DGC and SFC) and roughage NDF level.
### Table 9 - Influence of corn processing and level of NDF from sugarcane bagasse on growing performance of Nellore bulls (Melo, 2015)

<table>
<thead>
<tr>
<th></th>
<th>Ground corn</th>
<th>Steam-flaked corn</th>
<th>Processing</th>
<th>NDF level(^1)</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>7</td>
<td>10</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>8.73</td>
<td>9.59</td>
<td>9.36</td>
<td>9.58</td>
<td></td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>1.15</td>
<td>1.29</td>
<td>1.23</td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td>G:F</td>
<td>0.132</td>
<td>0.135</td>
<td>0.131</td>
<td>0.129</td>
<td></td>
</tr>
<tr>
<td>Hot carcass weight, kg</td>
<td>272</td>
<td>276</td>
<td>272</td>
<td>272</td>
<td></td>
</tr>
<tr>
<td>Dressing, %</td>
<td>55.8</td>
<td>55.4</td>
<td>55.1</td>
<td>55.0</td>
<td></td>
</tr>
<tr>
<td>12(^{th})-rib fat, mm</td>
<td>3.93</td>
<td>3.68</td>
<td>4.00</td>
<td>3.60</td>
<td></td>
</tr>
<tr>
<td>Fecal starch, % DM</td>
<td>16.3</td>
<td>14.7</td>
<td>12.3</td>
<td>11.7</td>
<td></td>
</tr>
<tr>
<td>Starch digestibility, %</td>
<td>90.4</td>
<td>91.5</td>
<td>93.1</td>
<td>93.6</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) L: linear effect, Q: quadratic effect of forage NDF level.

### Table 10 - Influence of corn processing and level of NDF from corn silage on growing performance of Nellore bulls (Sitta, 2016)

<table>
<thead>
<tr>
<th></th>
<th>Ground corn</th>
<th>Steam-flaked corn</th>
<th>Processing</th>
<th>NDF level(^1)</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>7</td>
<td>10</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>8.55</td>
<td>8.85</td>
<td>9.45</td>
<td>9.50</td>
<td></td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>1.44</td>
<td>1.49</td>
<td>1.57</td>
<td>1.48</td>
<td></td>
</tr>
<tr>
<td>G:F</td>
<td>0.168</td>
<td>0.169</td>
<td>0.166</td>
<td>0.157</td>
<td></td>
</tr>
<tr>
<td>Hot carcass weight, kg</td>
<td>280</td>
<td>284</td>
<td>288</td>
<td>293</td>
<td></td>
</tr>
<tr>
<td>Dressing, %</td>
<td>54.8</td>
<td>55.0</td>
<td>54.8</td>
<td>56.8</td>
<td></td>
</tr>
<tr>
<td>12(^{th})-rib fat, mm</td>
<td>3.83</td>
<td>3.93</td>
<td>4.56</td>
<td>4.41</td>
<td></td>
</tr>
<tr>
<td>Fecal starch, % DM</td>
<td>14.5</td>
<td>22.2</td>
<td>21.4</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>Starch digestibility, %</td>
<td>91.4</td>
<td>85.3</td>
<td>86.1</td>
<td>91.8</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) L: linear effect, Q: quadratic effect of forage NDF level.
Including fibrous byproducts in finishing feedlot diets may also altering fiber requirement. Feedlot producers who use digestible fiber by-products in feedlot diets have typically determined optimal levels of roughage in such diets largely by ‘trial and error’ (Galyean and Hubbert, 2014).

Miller et al. (2009) compared increased levels of alfalfa hay (3%, 6%, 9%, 12% and 15% of DM) in steam flaked corn-based diets with 25% dried distillers grains fed to finishing heifers. Alfalfa hay increased DMI quadratically (greatest at 12% hay). The ADG was increased by 7.7% for 12% compared with 3% hay, whereas the feed efficiency was not affected by roughage level.

With dry-rolled corn-based diets that contained 25% of wet distillers grains plus solubles, Hales et al. (2013) studied the influence of alfalfa hay levels (2%, 6%, 10% or 14% of diet DM) on the performance by finishing steers. Increasing alfalfa hay from 2% to 6% increased DMI and ADG, whereas a further increase (10% and 14% of hay) decreased ADG. As expected, feed efficiency linearly decreased with increasing alfalfa level.

Burken et al. (2013) evaluated elevated levels of corn silage in finishing diets containing distillers grains (Table 11). As corn silage inclusion increased (from 15%), there was a linear decreased in DMI, ADG and feed efficiency, which is in opposite to the trend reported in previous meta-analysis of experiments where no NDF was supplied from by-products with a high digestible fiber concentration (Galyean and Defoor, 2003; Arelovich et al., 2008).

Table 11 - Effect of corn silage level on the performance of finishing steers fed a diet containing 40% of distillers grains with solubles (Burken et al., 2013)

<table>
<thead>
<tr>
<th>Item</th>
<th>Level of corn silage1, % diet DM</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.5</td>
<td>10.3</td>
<td>10.3</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>1.83</td>
<td>1.78</td>
</tr>
<tr>
<td>G:F</td>
<td>0.175</td>
<td>0.172</td>
</tr>
<tr>
<td>Dressing, %</td>
<td>63.3</td>
<td>62.6</td>
</tr>
<tr>
<td>Hot carcass weight, kg</td>
<td>408</td>
<td>401</td>
</tr>
</tbody>
</table>

1Corn silage replaced a 50:50 blend of DRC:HMC.

2L: linear effect of corn silage level.

May et al. (2011) compared three levels of alfalfa hay (7.5%, 10% or 12.5%) in steam flaked corn-based diets with two levels of distillers grain (15 or 30%). The DMI tended to increase (linearly) as alfalfa level increased, with no indication of an interaction between levels of distillers grain and roughage.
Although byproducts typically contain large amounts of fiber, using grain byproducts as a replacement for fiber from traditional forages is not advised (NRC, 2016). Galyean and Hubbert (2014) recommended that little or no roughage value should be assigned to NDF in grain byproducts, such as corn gluten feed and distillers grains. It may be thought for citrus pulp and soybean hulls, as well.

Nowadays the optimal level of NDF from roughage is not well defined across the broad range of feed ingredients and conditions encountered in practical feedlot production. The claimed interaction between roughage levels, grain processing and byproducts are not consistent in finishing diets. In high-grain diets, it seems possible a little (no substantially) decreasing in dietary roughage levels when digestible by-products are fed.

**All-Concentrate Diets**

The interest in feeding animals without roughage is no innovation (Davenport, 1897; McCandlish, 1923; Geurin *et al.*, 1956). All-concentrate diets (without roughage) have been showed to be technically feasible for finishing beef cattle for more than half a century ago (Preston and Willis, 1974). In some circumstances, feedlot operations would show management benefits if roughage could be eliminated from the system.

When diets based on processed grains are fed to finishing cattle (e.g. ground, flaked, high-moisture), a minimal inclusion of roughage is required to optimize animal health and performance (see the topics above). However, including substantial levels of roughage in diets based on unprocessed whole shelled corn (WSC) often increases DMI (as in diets with processed grain) and ruminal passage rate, resulting in lower grain digestibility, lower or unchanged animal performance, and poorer feed efficiency (Vance *et al.*, 1972; Cole *et al.*, 1976; Milton *et al.*, 1994; Traxler *et al.*, 1995). In whole shelled corn (WSC) based diets, less than one-third of starch entering the abomasum disappeared postruminally (Owens, 2005). Then, a diet composed of WSC should be fed to feedlot cattle without or with a very low level of roughage that permits grain to be retained, ruminated, and fermented in the rumen. In US feedlots, roughage level seldom exceeds 5% of diet DM when WSC is being fed (Owens *et al.*, 1997).

In last decades, the interest in diets based on WSC steeply increased in Brazil. A series of trials were carried-out to compare flint WSC based diets
with ‘traditional’ rations containing roughage and processed grains (Table 12). Compared with dry ground corn based diets, all-concentrate WSC diets decreased DMI by 30%, ADG by 16%, whereas increased feed efficiency by 11%, with no effect on carcass dressing percentage. Stand on two experiments, diets containing 85% flint WSC + 15% pelleted supplement led to lower DMI (-21%), ADG (-31%) and feed efficiency (-11%) than SFC based diets. Therefore, depending on grain processing (availability and cost), roughage availability (and price), meat price and feedlot operational costs, feeding all-concentrate diets based on WSC may or may not be advantageous.

High corn price is a strong incentive for cattle producers looking for cheaper feedstuffs which would replace corn without substantially reducing gain and feed efficiency. Katsuki (2009) evaluated the partial replacement of flint WSC with soybean hulls (0%, 15%, 30% and 45%) on the performance of finishing steers. Exchanging 15% to 30% of WSC with soybean hulls optimized animal performance by significantly increase DMI and numerically increase ADG and feed efficiency. Replacing up to 30% of WSC with soybean hulls (Zarpelon et al., 2015) or whole grain oat (Borges et al., 2011) has also showed technical benefits for finishing lambs. However, total replacement of WSC with whole grain oat or whole grain rice significantly decreased ADG (1.30, 1.07 and 0.71 kg/d, respectively) and feed efficiency (0.165, 0.125 and 0.089) of finishing cattle (Argenta, 2015).
### Table 12 - Performance of finishing cattle fed traditional (roughage + processed grain) or whole shelled corn (WSC) based diets

<table>
<thead>
<tr>
<th>Reference</th>
<th>Diet</th>
<th>DMI, kg/d</th>
<th>Δ&lt;sup&gt;1&lt;/sup&gt;</th>
<th>ADG, kg/d</th>
<th>Δ&lt;sup&gt;1&lt;/sup&gt;</th>
<th>G:F</th>
<th>Δ&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Dressing, %</th>
<th>Δ&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandarino et al. (2013)</td>
<td>85% WSC + 15% pelleted supplement</td>
<td>8.52</td>
<td>1.25</td>
<td>0.147</td>
<td>58.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25% com silage + 75% GC and soybean hulls based concentrate</td>
<td>9.84</td>
<td>-15%</td>
<td>1.55</td>
<td>-24%</td>
<td>0.158</td>
<td>-7%</td>
<td>58.7</td>
<td>0%</td>
</tr>
<tr>
<td>Neumann et al. (2015)</td>
<td>80% WSC + 20% supplement</td>
<td>6.84</td>
<td>1.35</td>
<td>0.197</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>45% com silage + 55% concentrates</td>
<td>7.61</td>
<td>-11%</td>
<td>1.278</td>
<td>5%</td>
<td>0.168</td>
<td>15%</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>45% oat hay + 55% concentrates</td>
<td>8.17</td>
<td>-19%</td>
<td>1.226</td>
<td>9%</td>
<td>0.150</td>
<td>24%</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>Maia Filho et al. (2016)</td>
<td>85% WSC + 15% pelleted supplement</td>
<td>6.83</td>
<td>1.22</td>
<td>0.179</td>
<td>52.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25% grass silage + 75% citrus pulp based concentrate</td>
<td>9.4</td>
<td>-38%</td>
<td>1.41</td>
<td>-16%</td>
<td>0.150</td>
<td>16%</td>
<td>52.7</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>31% grass silage + 69% GC based concentrate</td>
<td>9.5</td>
<td>-39%</td>
<td>1.57</td>
<td>-29%</td>
<td>0.165</td>
<td>7%</td>
<td>52.7</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Dry ground corn based diets vs. all-concentrate WSC based diets*
<table>
<thead>
<tr>
<th>Study</th>
<th>Diet Description</th>
<th>ΔW</th>
<th>ΔR</th>
<th>ΔH</th>
<th>ΔG</th>
<th>ΔN</th>
<th>ΔP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carvalho et al. (2016)</td>
<td>85% WSC + 15% pelleted supplement</td>
<td>6.9</td>
<td>0.93</td>
<td>0.135</td>
<td>59.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Nellore</td>
<td>30% com silage + 70% GC based concentrate</td>
<td>10.4</td>
<td>-51%</td>
<td>1.36</td>
<td>-46%</td>
<td>0.131</td>
<td>3%</td>
</tr>
<tr>
<td>Carvalho et al. (2016)</td>
<td>85% WSC + 15% pelleted supplement</td>
<td>10.2</td>
<td>1.82</td>
<td>0.178</td>
<td>57.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Angus</td>
<td>30% com silage + 70% GC based concentrate</td>
<td>13.7</td>
<td>-34%</td>
<td>1.96</td>
<td>-8%</td>
<td>0.143</td>
<td>20%</td>
</tr>
<tr>
<td>Average (min. to max.)</td>
<td>-30%</td>
<td>-16%</td>
<td>11%</td>
<td>0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-51% to -11%)</td>
<td>(-46% to +9%)</td>
<td>(-7% to +24%)</td>
<td>(0% to +1%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Steam-flaked corn based diets vs. all-concentrate WSC based diets*

<table>
<thead>
<tr>
<th>Study</th>
<th>Diet Description</th>
<th>ΔW</th>
<th>ΔR</th>
<th>ΔH</th>
<th>ΔG</th>
<th>ΔN</th>
<th>ΔP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maia Filho et al. (2016)</td>
<td>85% WSC + 15% pelleted supplement</td>
<td>6.83</td>
<td>1.22</td>
<td>0.179</td>
<td>52.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>38% grass silage + 62% SFC based concentrate</td>
<td>9.73</td>
<td>-42%</td>
<td>1.64</td>
<td>-34%</td>
<td>0.169</td>
<td>6%</td>
</tr>
<tr>
<td>Marques et al. (2016)</td>
<td>85% WSC + 15% pelleted supplement</td>
<td>8.4</td>
<td>1.21</td>
<td>0.144</td>
<td>57.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6% sugarcane bagasse + 94% SFC based concentrate</td>
<td>8.4</td>
<td>0%</td>
<td>1.55</td>
<td>-28%</td>
<td>0.185</td>
<td>-28%</td>
</tr>
<tr>
<td>Average (min. to max.)</td>
<td>-21%</td>
<td>-31%</td>
<td>-11%</td>
<td>2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-42% to 0%)</td>
<td>(-34% to -28%)</td>
<td>(-28% to +6%)</td>
<td>(+1% to +2%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Δ = (WSC diet – Traditional diet)/WSC diet.
Not long ago, three trials compared the effects of roughage level on the performance of beef cattle fed flint WSC (Table 13). Marques et al. (2016) and Neumann et al. (2016) evaluated three levels of sugarcane bagasse on the performance of Nellore bulls and Brangus steers, respectively. Contadini et al. (2017) evaluated the performance of Nellore bulls fed WSC with three levels of grass hay. An overall appraisal suggests that adding roughage to WSC based diets increased DMI and ADG ‘quadratically’, with nil effects on carcass dressing percentage. Nonetheless, highest levels of roughage (i.e. >7%) decreased feed efficiency by 7 to 18% (Neumann et al., 2016; Contadini et al., 2017). Hence, when roughage is available, it may be included at low levels (i.e. 3 to 5% of DM) in WSC based diets.

Table 13 - Influence of roughage level on the performance of finishing cattle fed whole shelled corn (WSC) based diets

<table>
<thead>
<tr>
<th>Reference</th>
<th>Roughage source</th>
<th>Roughage level</th>
<th>DMI</th>
<th>ADG</th>
<th>G:F</th>
<th>Dressing, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marques et al. (2016)</td>
<td>Sugarcane bagasse</td>
<td>0</td>
<td>8.4</td>
<td>1.21</td>
<td>0.144</td>
<td>57.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>10.5</td>
<td>1.58</td>
<td>0.150</td>
<td>57.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>10.1</td>
<td>1.57</td>
<td>0.155</td>
<td>57.4</td>
</tr>
<tr>
<td>Neumann et al. (2016)</td>
<td>Pelleted sugarcane bagasse</td>
<td>0</td>
<td>8.4</td>
<td>1.43</td>
<td>0.170</td>
<td>56.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>9.4</td>
<td>1.62</td>
<td>0.173</td>
<td>55.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>9.6</td>
<td>1.54</td>
<td>0.161</td>
<td>55.0</td>
</tr>
<tr>
<td>Contadini et al. (2017)</td>
<td>Grass hay</td>
<td>0</td>
<td>6.5</td>
<td>0.77</td>
<td>0.118</td>
<td>55.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>8.2</td>
<td>1.41</td>
<td>0.172</td>
<td>54.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>9.4</td>
<td>1.33</td>
<td>0.141</td>
<td>54.2</td>
</tr>
</tbody>
</table>

Considering the possible benefits of including low levels of roughage and partially replacing WSC with soybean hulls, Monteiro et al. (2017) compared the performance of F1 British × Nellore young bulls fed diets containing WSC, soybean hulls, pelleted supplement, without or with sugarcane bagasse (2.5% of DM) (Table 14). In agreement with previous trials using either yellow dent whole corn (Milton et al., 1994; Traxler et al., 1995) or flint whole corn (Marques, 2016), a low inclusion of roughage increased DMI and ADG, without
affecting feed efficiency. Therefore, the diet containing 2.5% of sugarcane bagasse resulted in a shorter finishing period.

**Table 14** - Performance of young bulls fed diets based on whole shelled corn and soybean hulls, without (CON) or with sugarcane bagasse (BAG, 2.5% of DM) (Monteiro et al., 2017)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CON</th>
<th>BAG</th>
<th>Δ1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane bagasse, % DM</td>
<td>-</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Whole shelled corn, % DM</td>
<td>56.5</td>
<td>54.0</td>
<td></td>
</tr>
<tr>
<td>Soybean hulls, % DM</td>
<td>30.0</td>
<td>30.0</td>
<td></td>
</tr>
<tr>
<td>Pelleted supplement, % DM</td>
<td>13.5</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>7.78</td>
<td>8.36</td>
<td>+7.5%</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>1.35</td>
<td>1.49</td>
<td>+10.4%</td>
</tr>
<tr>
<td>G:F</td>
<td>0.174</td>
<td>0.178</td>
<td>ns</td>
</tr>
<tr>
<td>Final shrunk body weight2, kg</td>
<td>486</td>
<td>490</td>
<td>ns</td>
</tr>
<tr>
<td>Hot carcass weight, kg</td>
<td>272</td>
<td>274</td>
<td>ns</td>
</tr>
<tr>
<td>Dressing, %</td>
<td>54.8</td>
<td>54.6</td>
<td>ns</td>
</tr>
<tr>
<td>Marbling score</td>
<td>3.76</td>
<td>3.88</td>
<td>ns</td>
</tr>
<tr>
<td>NEm diet, Mcal/kg DM</td>
<td>1.96</td>
<td>1.95</td>
<td>ns</td>
</tr>
<tr>
<td>NEg diet, Mcal/kg DM</td>
<td>1.31</td>
<td>1.30</td>
<td>ns</td>
</tr>
<tr>
<td>Finishing period, d</td>
<td>108</td>
<td>100</td>
<td>-8%</td>
</tr>
</tbody>
</table>

1Δ = (BAG – CON)/CON diet; ns: not significant.
2Animals were slaughtered upon achieving the targeted final weight (~ 490 kg).

**Summary**

Fiber level and source have potential to impact animal performance and feedyard profit. Consider peNDF (measured by bioassay) for formulating finishing feedlot diets is theoretically more adequate than replace roughages on a DM or NDF basis, especially when using non-traditional fiber sources.

Nowadays, the optimal level of roughage (or peNDF) is not well defined across the broad range of feed ingredients and conditions encountered in beef cattle industry. The appraised literature suggests values from 7 to 13% of peNDF (or roughage NDF) to optimize NEg intake and ADG in ‘traditional’ diets, whereas feed efficiency is decreased with roughage levels, in almost all cases. The claimed interactions between roughage level, grain processing and byproducts are not consistent in finishing diets. In high-grain diets, it seems
possible a little (not substantial) decrease in dietary roughage levels when digestible by-products are fed. Hence, feedlot nutritionists must also rely on their experience when formulating high-concentrate feedlot diets.

Whole shelled corn based diets often decrease DM intake and ADG, but increase feed efficiency when compared with ‘traditional’ diets based on flint dry ground corn. However, when WSC diets are compared with steam-flaked corn based diets the scenario is in favor of grain processing.

In all-concentrate diets based on whole shelled corn, up to 30% of the corn can be replaced with soybean hulls. Including low levels of roughage (3 to 5%) improves animal performance of finishing cattle fed WSC diets. These strategies can be adopted together.

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ABSTRACTS
SCREENING OF LACTIC ACID BACTERIA STRAINSTO ENHANCE THE QUALITY OF CORN SILAGE HARVESTED AT LATE MATURITY

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Keywords: epiphytic bacteria, inoculant, plant maturity

Introduction: The whole-corn plant ensiling process is more difficult and fermentation is impaired with the increase of corn maturity. The use of inoculants can be an alternative to improve the fermentation profile. The aim of this research was to study the effects of lactic acid bacteria (LAB) strains isolated from farm corn silages on fermentation products, spoilage micro-organisms and aerobic stability of corn silages ensiled at late maturity.

Material and methods: Six LAB strains (UFLASLM40, UFLASLM4 and CCMA765 (Lactobacillus farraginis); CCMA778 (L. plantarum); UFLASLM76 (L. buchneri); UFLASLM127 (Pediococcus acidilactici)) previously isolated from farm corn silages and selected based on laboratorial tests were evaluated in experimental silos. The strain CCMA170 (L. hilgardii) isolated from sugarcane silage was also evaluated (Ávila et al., 2014). Corn plants were harvested with 450 g kg⁻¹ of DM. Inoculants were homogenized with the forage (6 log cfu g⁻¹) and compacted to a density of 535±21.0 kg of fresh matter m⁻³. The silos were stored for 10, 32 and 100 days. Samples were removed from fresh forage and from silages to make a water extract. Sequential 10-fold dilutions were prepared, and yeasts and filamentous fungi were enumerated on dichloranrosebengal chloramphenicol medium at 28°C for 72 h. The contents of alcohol and acids were measured by high-performance liquid chromatography equipped with acation exchange column (Shimadzu Shim-pack SCR-101H). After 100 d of ensiling, samples were removed from each silo and placed in plastic buckets to assess the aerobic stability, defined as the number of hours the silage remained stable before rising more than 2°C above the ambient temperature. The experiment was carried out in a completely randomized design, in a factorial arrangement consisting of 8 silages (7 LAB strains and a control without inoculant) and 3 times of storage. The means were compared by the Scott-Knott test at P ≤ 0.05.
**Results and Discussion:** The strains of LAB found a challenging environment for their metabolic activity, such as high DM (450 g kg\(^{-1}\)). Despite the unfavorable condition, a high molds and yeast population were observed in fresh corn (6.0 and 6.8 log cfu g\(^{-1}\), respectively). With 10 days of storage the silages without inoculant (control) showed higher (P < 0.01) yeasts (3.95 log cfu g\(^{-1}\)) and molds (2.90 log cfu g\(^{-1}\)) counts than other silages. At 32 and 100 days the higher yeast count (P < 0.01) was observed in the silages control and inoculated with strains CCMA791 and CCMA778, while the silages with others strains were lower than 2.0 log cfu g\(^{-1}\). The silages inoculated with strains of *L. farraginis*, *L. plantarum* and *L. buchneri* did not show growth of molds. After 32 days of storage the population of molds reduced (P < 0.01) in silage control (2.47 log cfu g\(^{-1}\)) and with strains CCMA791 and CCMA170 (< 2.00 log cfu g\(^{-1}\)). In general, the silage control had lower concentration of lactic acid than silages inoculated with homofermentative strains (CCMA 778 and CCMA791) and lower concentration of acetic acid than heterofermentative strains. At 10 days of storage the inoculation with strain UFLASLM40 resulted in higher concentration of lactic acid (67.9 g kg\(^{-1}\) of DM). It was observed reduction of lactic acid concentration (P < 0.01) during the storage period, except in the control and inoculated silages with strains CCMA778, CCMA791 e CCMA170. At the end of the evaluation period, the higher concentration of acetic acid (P < 0.01) was in silage with strain UFLASLM 76 (*L. buchneri*) (24.5 g kg\(^{-1}\) of DM), followed those inoculated with strains *L. farraginis* (UFLASLM40, UFLASLM4 and CCMA765) and *L. hilgardii* (CCMA170). Propionic and butyric acids were not detected. After 100 days of storage, the silages with the strains *L. farraginis* presented the lower concentrations of ethanol (P < 0.01) (mean of 17.4 g kg\(^{-1}\) of DM). The higher aerobic stability (P < 0.01) was observed in silages inoculated with strains UFLASLM40, UFLASLM4, CCMA765, UFLASLM76 and CCMA170 (mean of 114 h) than the control and inoculated silages with strain CCMA778 and CCMA791 (mean of 63 h).

**Conclusions:** The strains of *L. farraginis* isolated from farm corn silages are promising as inoculants for corn silage when whole-plant corn harvested at late maturity. However, more information is needed to evaluate the efficiency of these strains.
YIELD AND ECONOMIC PERFORMANCE OF CORN HYBRIDS FOR SNAPLAGE

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Keywords: ear corn silage, corn varieties, forage yield

Introduction: In recent years, snaplage has been produced on several Brazilian farms due to the improved harvesting equipment availability. Increasing input costs, accompanied by prospects for moderate to no increases in beef and milk prices in the years ahead, stress the need for minimizing cost of feeds. Cost of growing and ear yield among corn varieties vary considerably, resulting in different economic choices of hybrids. Thus, we hypothesize that there are varieties with more potential to make snaplage. The aim of this study was to examine commercial corn hybrids on cost of growing and key agronomic and ear traits.

Materials and Methods: Eleven corn hybrids from seven seed companies (Agroceres, Biomatrix, Dekalb, Dow AgroSciences, Limagrain, Pioneer, Syngenta) were grown at 70,000 plants/ha on three replicate plots (4 x 6 m) in each of three blocks in October 2017, in Lavras, Brazil (21°14′ S, 44°58′ W). Temperatures ranged from 12.5 to 33.6 °C and rainfall was 776 mm during the growing season. Costs of seed, fertilization, and control of weeds, pest and diseases were recorded for determining cost of growing. Costs of application to control pest and diseases were considered according to hybrid susceptibility. In practice, all hybrids received a maximum number of applications in order to standardize growing conditions. Hybrids were harvested at kernel black layer formation (physiological maturity) by removing ears from two rows in each plot. Ears were weighed and split into two subsamples. One subsample was processed and oven-dried at 60°C for 72 h to determine dry matter (DM) content. The second subsample was split into kernels, husks, and cob, weighed and oven-dried. Ear DM yields were standardized at 35% moisture. The experimental design was randomized complete blocks. Data were analyzed using ExpDes package of R system, followed by a Scott-Knott test at P ≤ 0.05.

Results and Discussion: Kernel moisture content averaged 29.7% for three hybrids and 25.9% for eight hybrids (P = 0.003). Ear moisture content was
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38.7% for one hybrid, 36.2% for three hybrids, and 32.1 for seven hybrids (P < 0.001). The corrected ear yields averaged 20.4, 16.6, and 12.6 tons of DM/ha for a group of three, six, and two hybrids, respectively (P < 0.001). The proportion of kernels per ear was 76.8% for three hybrids and 69.5% for eight hybrids. The cost of seed ranged from $121 to $212 per bag. The control of pest (i.e., Spodoptera frugiperda) occurred four times for one hybrid, three times for two hybrids, twice for six hybrids, and once for two hybrids. Four hybrids needed application against foliar disease (two applications for two hybrids and one application for two hybrids). The costs of pesticides and fungicides among hybrids varied from $18 to $54/ha and from $23 to $45/ha, respectively. The cost of growing ranged from $39.9 to $68.5/ton DM. The three hybrids that had the greater ear yields also showed the lower unit costs (on average $40.4/ton DM). It is crucial because cost of forage in the ration can be minimized by reducing unit costs. In the current transgenic era, farmers should compare hybrid performance and evaluate its consistency of performance. The hybrid should offer high yields of ear and pest and disease resistance. Furthermore, pay attention to seed cost because a high-cost seed does not always guarantee the desirable traits.

Conclusions: Animal performance is the ultimate quality test of a forage, but there are a number of agronomic considerations before making snaplage. Among the eleven corn hybrids tested in this study, three of them showed greater yield and economic performance. One of these three hybrids had greater proportion of kernels per ear, which may positively affect nutritive value of snaplage. Farmers should pay attention to corn hybrids traits in order to have high net return over feed costs.
Determining the Optimal Timing of Marandu Palisade Grass Harvest After Sowing

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Keywords: Agrometeorological models, Brachiaria, Growth curves, Phenology.

Introduction: Information about the correct moment to put animals in pastures for the first time after sowing is still unknown. The objective of this study was to characterize the distribution of the morphological components of Urochloa brizantha cv. Marandu during the establishment phase. In addition, modeling the biomass accumulation based on days after sowing (DAS) and development degree-day (GDD) to define the optimal timing for the first harvest or defoliation event.

Material and methods: The study was carried out in Lavras, MG (21 ° 14 'S, 44 ° 58' W and 919 meters above sea level). Plants were cultivated in pots with 6 dm³ of soil capacity. Soil acidity and fertility were set to levels as recommended for palisade grass sowing. Manual irrigation and N fertilizations were performed throughout the experiment for growth homogeneity. Seeding was performed on September 21, 2016. Thirty seeds were manually selected and sowed in each pot. Seeds were equally distributed in the pot and buried at 25 mm depth through a wooden mold. After the total emergence of seedlings, successive thinning was performed. Two plants were left per pot at the end of 30 days of sowing. The experiment was conducted using 90 pots, and three replicates were used per evaluation in 30 different weeks after sowing. Plant growth was determined by weighing the biomass of the plants after destruction of the pots. On every week, three pots were randomly selected for evaluation. The morphological components of the aerial part were separated into: Leaves, stem + reproductive stem and dead leaves. Morphological components were dried separately in a forced-draft oven at 55 °C for 72 h to obtain the dry masses. The distribution of morphological components of the primary tillers were evaluated over time in proportion to the total biomass accumulated. The biomass production above ground level were described based on DAS and GDD through the nonlinear regression Logistic model. The nlsfit and nls functions of the easynls and nlme packages in the statistical program R were used.

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curve adjustment quality was determined by determination coefficient ($R^2_{aj}$) and by the Bayesian information criterion (BIC).

**Results and Discussion:** The leaf proportion increased up to $51 \pm 3.5$ DAS (or $606 \pm 44$ GDD), reaching up to 80% of the total biomass above soil level. From $58 \pm 3.5$ DAS (or $692 \pm 42$ GDD), the proportion of stems and dead leaves increased until the end of the trial, while leaf proportion reduced. At $121 \pm 3.5$ DAS (or $1450 \pm 42$ GDD) we observed the transition between vegetative and reproductive stages. Reproductive stage was characterized by the stem elongation phase, particularity on tropical forages. The biomass produced above soil level (Y, g tiller$^{-1}$) was adjusted by the Logistic model presenting the following equations: $Y = \frac{2.413}{1+e^{(-0.060*(DAS-90.02))}}$, $R^2_{aj} = 0.9993$ and BIC = 38.53; and $Y = \frac{2.409}{1+e^{(-0.005*(GDD-1076))}}$, $R^2_{aj} = 0.9999$ and BIC = 38.35. The GDD model showed a better adjustment of the curve compared to the DAS model on biomass accumulation per tiller.

**Conclusions:** The quantitative growth analysis and morphological distribution over time were capable to define the optimal timing to first graze. Around 58 DAS (or 692GDD) was considered the optimal timing to use the pasture after sowing. The GDD model developed based on temperature can be used in other locations since water is not limiting.
EFFECTS OF SUPPLEMENTING EXOGENOUS AMYLASE AND PROTEASE ON ENHANCING IN VITRO DRY MATTER AND STARCH DIGESTIBILITY OF DENT CORN GRAIN

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Keywords: amylase, starch, protease

Introduction: Starch is a highly digestible and energy dense feed component that typically ranges from 20-30% DM in rations fed to lactating dairy cows. However, rate and extent of ruminal starch fermentation varies considerably. Starch granules in wheat, barley, and oats are more readily fermented compared to corn and the differences are attributed to the presence of protein matrix surrounding starch in corn that are insoluble and resistant to digestion, decreasing access of rumen microbial enzymes to starch granules. Corn is the most common energy source used in dairy diets primarily because of its greater starch content contributing to about 75% of the energy value in corn grain. Thus, improving corn starch utilization could lower starch content of the diet without affecting its nutritional value thereby decreasing feed costs. Supplementing exogenous amylases and proteases may be an effective alternative to improve corn starch utilization. The objective of this study was to evaluate the efficacy of exogenous amylases and proteases on in vitro dry matter (IVDMD) and starch digestibility (IVSD) of dent corn grain. We hypothesized that adding an exogenous amylase and protease would increase IVDMD and IVSD.

Material and methods: Two experiments were conducted to evaluate ten exogenous amylases (experiment 1), and three exogenous proteases (experiment 2) using in-vitro batch culture of buffered-rumen fluid. Rumen fluid was collected from three ruminally-cannulated lactating Holstein cows consuming corn silage based total mixed rations (42:58% forage:concentrate). Substrate used was dried and 4-mm ground dent corn grain (0.5 g) weighed in F57 Ankom bags. For experiment 1, treatments were control (no enzyme) and ten different amylases (1LAT, 2AK, 3AC, 4Cs4, 5Trga, 6Afuga, 7Fvga, 8Star, 9Syn and 10Tg), applied individually at 0.25, 0.50, 0.75 and 1.0 mg of enzyme/g of substrate dry matter (DM). For experiment 2, treatments were control (no enzyme) and three different proteases (11P14L, 12P7L and 13P30L) applied at 0.25, 0.50, 0.75 and 1.0 mg of enzyme/g of substrate DM. For both experiments, treatments were applied directly to the substrate in filter bags followed by
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adding buffered rumen fluid (52 ml) to 160 ml serum vials containing bags. Serum vials were closed with rubber stoppers and sealed with aluminum seals. Samples were incubated for 7 h using 6 replicates per run for amylases and 4 replicates per run for proteases in three independent runs. Data were analyzed using the GLIMMIX procedure of SAS for both experiments. Dose was used as fixed effect in the model while run was considered a random factor. Treatment effects were declared significant at $P < 0.05$ while trends were defined at $0.05 \leq P \leq 0.10$.

**Results and Discussion:** In experiment 1, enzymes 2AK, 3AC and 10Tg were not effective ($P > 0.10$) in improving IVDMD and IVSD. Enzymes 1LAT, 5Trga and 8Star, increased IVDMD by 23, 47 and 62% and IVSD by 35, 41 and 58% respectively when added at the lowest dose (0.25 mg/g substrate), compared to the control. A dose-dependent effect ($P < 0.01$) was observed for enzymes 4Cs4, 6Afuga, 7Fvga and 9Syn. Both IVDMD and IVSD were increased by 82.9 and 85.9% respectively with highest dose of enzyme 6Afuga. For experiment 2, enzymes 11P14L and 12P7L increased ($P < 0.01$) IVDMD by 98 and 87 and IVSD by 57 and 64% respectively, when applied at the lowest dose. The highest dose of enzyme 13P30L increased ($P = 0.02$) IVDMD by 44.8% and IVSD by 30%, relative to the control.

**Conclusions:** Exogenous amylase and protease supplementation are effective in improving IVDMD and IVSD from dent corn using in-vitro batch culture of buffered-rumen fluid. Future *in vivo* studies are required to validate these findings before these enzyme additives can be recommended for improving digestibility of ruminant feeds.
EFFECT OF NITROGEN SOURCE AND LEVEL ON AMMONIA VOLATILIZATION IN MARANDU-GRASS PASTURELANDS

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Keywords: nitrogen fertilization, N-NH$_3$ volatilization, environmental impacts, urea.

Introduction: Urea is the main nitrogen (N) source used in the fertilization of forages grasses, which increases forage production and quality, being an important nutrient for pasture management. However, higher N losses mainly by ammonia volatilization are very frequently, and cause reduction in the nitrogen usage efficiency by grasses. Due to urea presents higher rates of N losses by volatilization is necessary to find alternatives to reduce N losses and increase the efficiency of fertilization. The aim of this research was quantify ammonia volatilization by application of different nitrogen sources and levels in marandu-grass (Brachiaria brizantha Stapf.) pastures.

Material and methods: The research was conducted in the experimental area of Universidade Estadual Paulista (Unesp), Jaboticabal, SP, Brazil. The experimental design was randomized blocks, with ten treatments and four replications. The treatments were three levels of N top-dressed (90, 180 and 270 kg N ha$^{-1}$), three sources of N (urea, ammonium nitrate and ammonium sulfate) and, a control treatment without nitrogen application. Volatilized NH$_3$ were collected using a free semi open chamber with a foam containing H$_2$SO$_4$ + glycerin. Samples were done at 1º, 3º, 5º, 9º, 14º and 21º day after nitrogen application. The N-NH$_3$ volatilized was determined by steam distillation using a semi micro Kjeldahl apparatus followed by titration. ANOVA was performed by F test. To compare nitrogen sources means Tukey test was applied and, to evaluate the effect of N levels polynomial orthogonal contrasts was performed.

Results and Discussion: Ammonia volatilization differed by source ($P < 0.001$), level of N ($P < 0.001$) and there was interaction between source and nitrogen level ($P < 0.001$). Total N-NH$_3$ losses increased linearly for all N sources. N losses in the form of NH$_3$ averaged for urea 13.92, 24.37 and 44.58%, for ammonium nitrate 2.02, 3.17 and 7.71% and, for ammonium sulfate 2.22, 3.10 and 5.25% for nitrogen level 90, 180 and 270 kg N ha$^{-1}$, respectively. Ammonia volatilization from the fertilizers studied followed the next order: urea.
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< ammonium nitrate < ammonium sulfate, which is explained by the variation in the N chemical groups in the fertilizer source studied. Urea has amidic N with higher susceptibility to urease, while the ammoniacal form of ammonium sulfate do not favors ammonia volatilization in soils.

**Conclusions:** The utilization of N fertilizations with nitric and ammoniacal N forms could be an efficient strategy to diminish N losses by volatilization in tropical pasturelands. In our study N losses were reduced in up to 85%, when compared to urea application. Once the source studied, are the three mains N fertilizers used in Brazil. Ammonium nitrate and ammonium sulfate can be an alternative to reduce the impact by N pollution in pasturelands.
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FUNGICIDE TREATMENT, COATING AND CONSERVATION OF HYBRID BRACHIDIA SEEDS

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Keywords: MAXIM® XL, dormancy, germination, Braquiária híbrida cv. Mulato II

Introduction: Technologies used in the production and commercialization of fodder seeds, such as chemical treatment and coating, have added value to the seeds of this species, enabling an increasingly competitive market. Among the innovations, chemical treatment is a tool that ensures protection to the seed in the field and during storage, however, research findings have shown that some products could, on certain occasions, reduce germination and seedling survival, due to the effect of phytotoxicity. Thus, the objective of this study was to evaluate the effect of chemical treatment and coating during storage on the physiological quality of hybrid brachiaria cv. Mulato II.

Materials and Methods: Four seed lots were used, produced by Dow AgroSciences Seeds & Biotechnology Brazil, and scarified by rubbing on rubber rollers. The seeds of each lot were homogenized and divided into a soil seed divider, then treated with MAXIM ® XL fungicide (250 mL / 100 kg of seeds) and coated. After treated with fungicide and the coating process, the seeds were packed in kraft paper bags and conditioned in conventional (21-30 °C) and cold chamber (10 °C) environment in Cravinhos/SP (latitude 21°20’25” south and longitude 47º43’46” west). The physiological evaluations of the seeds were performed every 90 days for 540 days of storage by germination and tetrazolium tests. A completely randomized design was adopted, with three replications of 100 seeds, in a 4x2x7 factorial scheme, which was four seed lots, two storage environments (conventional and cold chamber), and seven storage periods (0, 90, 180, 270, 360, 450, and 540 days). After data tabulation, means were submitted to a variance analysis and compared using Tukey test at 5% probability, for qualitative data, and polynomial regression analysis, for quantitative data.

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**Results and Discussion:** Differences among the evaluated lots were observed for germination and viability. Regarding germination, lots 3 and 4 were superior to the others, during all periods of storage. In viability, lots 2, 3 and 4 with 0 days of storage had higher percentage of viable seeds compared to lot 1, however, over time, lots 3 and 4 presented higher values. Where as the two environments, these showed differences after 270 days of storage, in which seed germination of conventional storage presented inferior results compared to the cold chamber. Seeds stored in cold chamber environment had a higher percentage of viable seeds, presenting lots 2 and 3 superior to the others. The variations of responses between the different evaluations have as main causes the different levels of dormancy presented in the seeds, even after the process of physical scarification and chemical treatment.

**Conclusion:** The seed quality conservation of hybrid brachiaria cv. Mulato II treated with MAXIM® XL and coated is affected by the storage environment. The refrigerated environment favors the maintenance of seed quality of hybrid brachiaria cv. Mulato II, however prevents the breakage of seed dormancy.
METHANE FLUXES FROM CATTLE EXCRETA IN MIXED AND MONOCULTURE MARANDU-GRASS PASTURE

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Keywords: Arachis pintoi, forage legumes, methane, pasture management

Introduction: In Crop-Livestock Sector the cattle excreta contribute to emission of greenhouse gases. Methane is an important gas because it has a heating potential of 21 to 28 times greater than CO₂. Therefore, the aim of this study was to determine methane (CH₄) fluxes from excreta of cattle grazed in Marandu-grass pastures (Brachiaria brizantha cv. Marand) with different sources of nitrogen.

Material and methods: The experiment consisted of two factors (pasture management and excreta type) in a randomized complete block design, with 5 replicates. The pastures were: 1) CONTROL: Marandu-grass pastures without nitrogen or legume; 2) FERT: Marandu-grass pastures fertilized with nitrogen (150 kg N ha⁻¹ year⁻¹); 3) MIXED: Marandu-grass pastures intercropped with Pinto peanut (Arachis pintoi cv. Amarillo). The excreta types were dung (1.6 kg/ treatment) and urine (1.0 L/ treatment) from heifers (353.1 ± 24.1 kg BW) grazing in the pastures. Static chambers were used to evaluate CH₄ emissions, which were determined by gas chromatography (flame ionization detector). The experimental period was 242 days. Posteriorly, ANOVA was performed, background emissions were compared with each treatment by Student’s t-test and the Tukey’s test was ran to determine differences among means of dung treatments.

Results and Discussion: During the whole experimental period, soil CH₄ production averaged -81 µg CH₄ m⁻² h⁻¹. Only dung differ from CH₄ soil basal emissions. For urine, pasture treatments did not differ. For dung, CH₄ fluxes differed among pasture treatments at the probability of 0.085. Methane fluxes

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were greater for FERT pastures (1459 µg CH₄ m⁻² h⁻¹) and lower for MIXED (183 µg CH₄ m⁻² h⁻¹) pastures, which did not differ from CONTROL (316 µg CH₄ m⁻² h⁻¹). Urine fluxes of CH₄ were 42, -135 and -29 µg CH₄ m⁻² h⁻¹ (FERT, MIXED, and CONTROL, respectively) and did not differ among treatments. The CH₄ fluxes differed between excreta type ($P < 0.0001$). Dung averaged 653 µg CH₄ m⁻² h⁻¹ and urine -41 µg CH₄ m⁻² h⁻¹. After voided dung has methanogenic microorganism and high amount of available carbon, which stimulated CH₄ production. Probably the highest fluxes found in the treatments FERT occurred due to more nitrogen for microorganism growing.

**Conclusions:** Pasture nitrogen fertilization stimulated methane production from dung, while legume inclusion did not differ from the treatments without N inclusion. Only dung was the source of methane.
AMBIENT TEMPERATURE AND PERFORMANCE OF ENZYME-MICROBIAL ADDITIVES ON THE FERMENTATIVE LOSSES OF SUGARCANE SILAGE

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Keywords: climate, effluent, forage conservation, inoculants

Introduction: Silage is the main technique of food conservation for ruminants. Crops such as maize, for example, have intrinsic characteristics that make it ideal for this purpose. However, other crops such as sugarcane have high productivity and economic interest for Brazil, but it needs additives to be used as silage due to the high fermentative losses by yeasts action, deriving to the high sugar content. Besides that, several microclimates present in the vast Brazilian territory collaborate to change and differ epiphytic microflora and influence microbial growth and enzyme performance, consequently, compromising additives efficiency.

Material and methods: The present study was realized at Centro de Pesquisas em Forragicultura, located at Canguiri Experimental Farm of the Federal University of Paraná, in Pinhais/PR. The sugarcane used was harvested in June 2017 and had 24% dry matter (DM), 15º brix and pH 5. The treatments were: control (without additive), Sil-All (P. acidipropionici and cellulase) and Fireguard (L. plantarum, P. acidilactici, P. pentosaceus, sodium benzoate, amylase, glucanase and xylanase). Also, the silage was stored in two controlled ambient temperatures – cold (18ºC) and hot (26ºC). A completely randomized design with three treatments and five replications was adopted, each in one environment, totaling 30 experimental units. The material was stored for 120 days in experimental silos with mean compaction 635 k gm⁻³. After this period, the silos were opened and the empty set (silo, cover, grid, screen and tissue) weighed to determine effluent losses. Gas losses and total DM losses were calculated by weight difference. Analysis of Variance was applied, and significant difference verified, the Tukey test (P < 0.05) was used. For the statistical analysis the software Statgraphics was used.
Results and Discussion: Among the silages stored in the cold environment, the Sil-All treatment had the highest total DM (20.1 g kg\(^{-1}\) DM) and gas losses (18.1 g kg\(^{-1}\) DM), while the effluent losses were similar between treatments, with mean 22.4 kg t\(^{-1}\) fresh matter (FM). Among the silages stored in the hot environment, the control and Sil-All treatments presented the highest total DM (19.5 and 20.3 g kg\(^{-1}\) DM, respectively) and gas losses (15.4 and 16.4 g kg\(^{-1}\) DM, respectively). The effluent losses also did not differ, with mean 42.9 kg t\(^{-1}\) FM. It is estimated that the highest effluent losses in the hot environment, about 20 kg t\(^{-1}\) FM, occurred due to the greater cell wall degradation and, consequently, the greater exposure of the cellular content, considering the deteriorating effect of higher temperatures on the structure of the plant cell. For the variables total DM losses and gas losses, the Sil-All treatment shows to be little affected by the environment temperature, including presenting the same result of untreated silage (control) under conditions of mild to hot temperatures.

Conclusions: The Fireguard additive had better performance, probably due to its composition, and had its effects improved in hot environment. The environment temperature influences the fermentative process of sugarcane silages, potentiating or neutralizing the effect of enzyme-microbial additives.
EFFECT OF PEPsin AND/OR AMYLASE ADDITIVES ON THE RUMINAL DEGRADABILITY OF REHYDRATED CORN GRAIN SILAGE

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Keywords: prolamin, protease, starch, zein.

Introduction: The high prolamin content of Brazilian corn endosperm confers low ruminal digestibility to starch. Several studies have been performed to improve the digestibility of corn starch. Among the techniques studied are the use of enzymes and rehydrated grain silage. Grain silage rehydration is an interesting technique for improving corn starch digestibility. The use of enzymes associated with the silage process may maximize the digestibility of the starch; however, the maximum temperature that can be reached in the grain fermentation process during silage is not known. Therefore, the objective of this work was to evaluate the temperature of silage on silage days, as well as ruminal degradability, ammonia concentration, and prolamin content of rehydrated corn silage treated with amylase and/or pepsin for a varying number of silage days.

Material and methods: Corn was ground to 5 mm and added to 1 g/kg of pepsin and/or amylase in a 2 × 2 factorial scheme: corn with amylase and pepsin (AP), corn with amylase (A), corn with pepsin (P), and control (corn sans amylase and pepsin; C). The milled dry corn was moistened to 40% moisture and ensiled for 0, 15, 30, 60, and 90 days in experimental polyvinyl chloride (PVC) silos. An electronic temperature recorder was included in each silo for collecting temperature measurements every hour for 25 days. Silage samples were incubated for 3, 6, 12 and 24 hours in the rumen of a non-lactating cow provided with ruminal cannula. Our statistical model considered the effect of amylase, pepsin, ensilage time, interaction between amylase and pepsin, interaction between amylase and time, interaction between pepsin and time, and interaction between the amylase/pepsin combination and time.

Results and Discussion: The average temperature of the silages was 21.6 °C and the maximum temperature was 33.2 °C. The addition of amylase and pepsin reduced the internal temperature of the silos. The addition of pepsin enhanced

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starch prolamin degradation; it also increased the ruminal degradation of corn grain ensiled for 90 days over that of non ensiled corn grain as follows: 29.8 to 41.4%, 31.8 to 45%, 45.1 to 63.2%, and 69.8 to 86.1% ($P < 0.04$) at the 3, 6, 12, and 24 hour ruminal incubation times, respectively. Adding pepsin and raising the silage time from zero to 90 days maximized the degradation of hydrophobic proteins in corn endosperm, thereby increasing the ammoniacal nitrogen content of the silage. Thus, 90 days of silage improved the ruminal degradation of dry matter in rehydrated corn grain silage.

**Conclusions:** Amylase did not affect the ruminal degradability of corn; in contrast, pepsin improved ruminal degradability all time points.
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ELEPHANT GRASS SILAGE WITH LEVELS OF OENOCARPUS BATAUA BY-PRODUCT STORED FOR A LONG TIME

Amanda Caroliny Marques Queiroz¹, Rita de Cássia Almeida de Mendonça¹, Claudia Marcia Serra Ferreira¹, Larissa Lourenço de Oliveira¹, Felipe Nogueira Domingues¹, Aníbal Coutinho do Rêgo¹

Keywords: dry matter recovery, effluent losses, moisture-absorbing additive

Introduction: By-products from oil seeds, such as Oenocarpus bataua, can be used as a moisture-absorbing additive during the ensiling of crops with low dry matter (DM) content. Their use depends on the availability in the region, on the cost of processing and on researches that demonstrate the effectiveness in decrease fermentation losses in the silo. In addition, the studies evaluating silage additives consider a short period of 60 to 90 days, considering the silage use in the same year. However, farmers can store the silage for long periods depending on the forage availability because of two different reasons: a) there is enough forage production from the pastures during the dry period, but it depends on the annual rainfall; b) the annual rainfall is quite variable that farmers must produce as much silage as they can during the rainy season of the year. Based on that we proposed to study if the effects of the moisture-absorbing additives persist even after a long period of storage. This study aimed to determine the effect of the of levels of patauá cake (PC) on the fermentative characteristics, microbiology composition and fermentative losses in elephant grass silage stored for 33 months.

Material and methods: The experiment was conducted at the Federal Rural University of Amazonia (Belém-PA, Brazil). The experiment was conducted in a completely randomized design, with five treatments represented by levels of PC (0.0, 7.0, 14.0, 21.0, 28.0%, based on natural matter (NM)) in the silage of elephant grass with five replicates. The elephant grass was harvested with 60 days of growth (DM = 18.76%) and chopped in a stationary forage-chopper. After processing, the grass and the PC were mixed in the previously defined proportions and packed in plastic buckets (15 L), containing sand in the bottom to quantify the effluent losses (average packing density = 707.00 ± 37.14 kg/m³ of NM). Silos were opened after 33 months and the levels of ammonia nitrogen (N-NH₃), volatile fatty acids (acetic, propionic and butyric) and yeast and molds counts were determined. In addition, the effluent losses and dry matter recovery

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(DMR) of the silages were evaluated. Data were submitted to linear regression analysis by using the GLM REG procedure of SAS (α=0.05), considering the fixed effect of PC and the random error in the model.

**Results and Discussion:** No effect ($P > 0.05$) of PC addition was observed on the fermentation products and fungi populations. The effect of the additive on these characteristics may have reduced after 33 months of storage. However, the N-NH$_3$ contents remained below 12%, considered as the maximum limit so that the silage is properly conserved. The concentrations of the acids are also below those recommended (propionic < 0.5, acetic < 2.0 and butyric < 0.1% DM). Effluent production decreased linearly ($P < 0.05$) as PC addition increased in elephant grass silage. This effect may be related to the increase in dry matter contents of the silages with the PC which has a high DM content (DM = 89.61%). There was a decreasing linear effect ($P < 0.05$) on DMR with the inclusion of PC. Elephant grass silages with PC had high concentration of nutrients (non-fibrous carbohydrates) which could be used as substrate by the microorganisms during the long period of storage, because a reduction in the concentration of fiber in neutral detergent occurred (70.4, 65.1, 61.9, 56.6 and 55.0%) with the addition of the cake, possibly causing a decrease in the dry matter content of the silage DMR.

**Conclusions:** The effect of patauá cake on the fermentative characteristics and microbiological composition was reduced through the long storage time. Therefore, the use of this by-product as a long-term moisture absorbing additive was effective in reducing silage effluent losses and keeping the silage well-preserved. Elephant grass silage treated with high levels of patauá cake show more nutrient losses after 33 months of storage.
EFFECTS OF RELOCATION OF CORN SILAGE AND MICROBIAL INOCULANTS ON THE TEMPERATURE AFTER AIR EXPOSURE

Rita de Cássia Almeida de Mendonça¹, Melany Simões de Souza¹, Camilo Guimarães Rodrigues Cruz¹, Amanda Caroliny Marques de Queiroz¹, Thiago Carvalho da Silva¹, Aníbal Coutinho do Régo¹

Keywords: Lactobacillus buchneri, Lactobacillus plantarum, maximum temperature, re-ensiling

Introduction: The temperature of corn silage is an important indicator of deterioration process in the ensiled mass. Relocated corn silages may undergo intense microbial activity, especially in the feed-out phase, due to the action of yeasts with a substantial increase of temperature in forage ensiled. This process may be more intense in tropical regions, since the ambient temperature may favor the metabolism microorganisms, accelerating the enzyme activity in the cells. Based on that, the objective of this study was to evaluate the effect of exposure time to air during the silage relocation and the application of microbial inoculants on the temperature of corn silage after air exposure.

Material and methods: The experiment was conducted in a completely randomized design, with a 4×6 factorial, with four replications. Studied factors were: microbial inoculant (without inoculant (WI); Lactobacillus plantarum + L. buchneri (LPLB); L. plantarum + Propionibacterium acidipropionici (LPPA); and L. buchneri (LB)) and time spent with relocation (TR); (non-relocated, 12, 24, 36, 48 and 60 hours of exposure before re-ensiling). The hybrid Pioneer 4285 was harvested at the 2/3 milk-line stage (~30% dry matter). Fresh-chopped forage was treated or not with microbial inoculants, at a final application rate of 1×10⁵ cfu/g fresh forage and packed in 20-L plastic buckets (~550 kg/m³). After 120 days after ensiling, the silages were exposed during the different times previously described (except the 0 h) and re-ensiled in a new bucket. Relocated and non-relocated silages were opened after 90 days of re-ensiling and 210 days of ensiling, respectively. After opening, silages from each replication were placed in a new bucket (~2 kg) without compaction and analyzes of the amplitude (AMP), maximum temperature (MT), times in hours to reach the maximum temperature (THM) during seven days of aerobic exposition. All data were subjected to ANOVA, including the fixed effects of microbial inoculant

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(MI), exposure time to air in the silage relocation (TR) and the interaction (MI×TR), and the means were compared by Tukey’s test (α=0.05).

**Results and Discussion:** There was no interaction effect on the AMP ($P > 0.05$). However, there was interaction effect on the MT and THM in relocated silages ($P < 0.05$). Non-relocated silages had higher AMP (8.0°C) compared with relocated silages (average 3.6°C), independently of the MI. The highest MT was observed in the WI and non-relocated silages, as well, in silages without inoculant when TR was 12 hours (29 and 26°C, respectively). The highest MT was observed in LPLB - treated silages when TR was 12, 24, 36 hours (25; 26 and 26°C, respectively). The highest MT was observed in the non-relocated silages treated with LB (33°C). Silages treated with LB had lower MT when TR was 36, 48 e 60 hours (27, 26 and 27°C, respectively) compared with non-relocated silages (33°C). Inoculated silages showed higher MT (average 27°C) compared with WI-silages when TR was 24 hours (23°C). The temperature elevation is an important indicator of aerobic deterioration. Thus, non-relocated silages were more unstable compared with relocated silages in the aerobic environment. Probably, the non-relocated silages had high content of residual lactic acid and soluble carbohydrates, which are substrates for yeasts. This group of microorganisms have the ability to metabolize these compounds in acid pH and aerobiosis and produce heat, CO$_2$ and water. The non-relocated silages without inoculant had lower THM (58 hours) compared with non-relocated silages treated with microbial inoculants (average 118 hours). Silages treated with LB had higher ($P < 0.05$) AMP (6.7°C) compared with to the other silages (average 3.6°C), independently of the TR. This indicates more aerobic deterioration which could be explained by the preservation effect during the first period of fermentation (90 days) that provided more substrates for the aerobic microorganisms at the final opening because those silages were not previously exposed to oxygen as the relocated ones.

**Conclusions:** The microbial inoculants LPLB, LPPA and LB do not improve variables relates to temperature of corn silage relocated. Silage relocation may decrease the effect of microbial inoculants, especially LB, and decrease the temperature variations after air exposure.
RELOCATED CORN SILAGES: CHANGES ON THE CHEMICAL COMPOSITION AND DRY MATTER LOSS OVER STORAGE TIME

Rosana Ingrid Ribeiro dos Santos¹, Rita de Cássia Almeida de Mendonça¹, Amanda Caroliny Marques de Queiroz¹, Daniel Augusto da Silva¹, Thiago Carvalho da Silva¹, Aníbal Coutinho do Rêgo¹

Keywords: insoluble fiber in neutral detergent, non-fibrous carbohydrates, relocation, re-ensiling

Introduction: The relocation of silages, which comprehends transferring material from one silo to another, is widely used by farmers to provide forage supply to the herd. After the process of transport, compaction and sealing in the new silo, the relocated silage will undergo a new fermentation process, which may improve or worsen some silage characteristics. Aerobic exposure during the relocation process can cause changes in the chemical composition of the silage due to the entry of oxygen into the mass and reactivation of microorganisms previously inactivated by the anaerobic environment. In addition, there is no information about what happens to this relocated silage during the time of storage until its utilization by the farmers. Thus, the objective of this work was to evaluate the effect of the storage time after the relocation on the chemical composition of corn silage.

Material and methods: The fresh-chopped corn was ensiled in a bunker silo with a density of 600 kg/m³, with approximately 32,5% of dry matter. After 150 days of ensiling, the silo was opened and the visible spoiled silage was removed from the panel. After that, the silage was removed from the panel and exposed to the air for nine hours. After air exposure, the silage was re-ensiled into 24 experimental silos where 9 kg of forage mass was placed to reach a density of 600 kg/m³ of natural matter. The experiment was conducted in a completely randomized experimental design, with the treatments represented by the storage times after silage relocation (4; 8; 16; 32; 64 and 128 days) and the control treatment (silage that was not relocated). Approximately 200g of silage was collected at the time of opening to evaluate the chemical composition. Samples were dried in a forced-air oven (55°C/72h) and then grounded in a Willey-type mill with a 1 mm diameter screen. We evaluated dry matter (DM), mineral matter (MM), crude protein (CP), insoluble fiber in detergent corrected for ash and

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protein (apNDF), acid detergent (ADF), and non-fibrous carbohydrates (NFC). Dry matter recovery (DMR) was determined considering the DM content of at the relocation and after the storage. Data were analyzed by using the PROC REG of SAS 9.2, and the regression analysis was performed for the “storage time”.

**Results and Discussion:** The contents of DM, OM, NFC and DMR decreased linearly when the storage time of relocated silages increased ($P < 0.05$). On the other hand, there was a linear increase ($P < 0.05$) with the advance of storage time after relocation for the concentrations of CP, MM, apNDF, ADF, and hemicellulose. This increase occurred proportionally to the reduction of NFC. Silages stored for prolonged periods such as those in the study in question tend to increase nutrient losses (especially soluble carbohydrates) due to nutrient degradation by microorganisms during anaerobic fermentation, which decreases NFC content. This was probably the case in the experiment in question, since before relocation, the silages remained ensiled for 150 days.

**Conclusions:** The increase of the storage time after the relocation reduces the concentration of nutrients in corn silage.
CHEMICAL COMPOSITION OF ELEPHANT GRASS SILAGES LEVELS OF OENOCARPUS BATAUA CAKE STORED FOR A LONG TIME

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Keywords: additive, dry matter, moisture-absorbing additive

Introduction: The production of elephant grass silage (Pennisetum purpureum) is a strategy to make livestock production less dependent on climatic conditions. However, most of the tropical grasses have low concentrations of dry matter (DM) and water-soluble carbohydrates at harvest time, which can compromise the fermentation process. The use of by-products from local industry, such as patauá (Oenocarpus bataua) cake may be used as moisture-absorbing additive in elephant grass silage. The use of this additive also can be an interesting alternative to improve nutritive value of the silage. In addition, the majority of the studies consider a short period of storage (60 to 90 days). However, farmers can store the silage for long periods depending on the forage availability because of different reasons. Therefore, this study aimed to determine the effect of the inclusion of patauá cake on on the chemical composition of elephant grass silages.

Material and methods: The experiment was conducted at the Institute of Animal Health and Production of the Federal Rural University of Amazonia, Belém-PA, Brazil. We used a completely randomized design, with treatments described by the levels of patauá cake (PC; 0.0; 7.0; 14.0; 21.0; 28.0% based on natural matter) in the silage of elephant grass with five replicates. The elephant grass was harvested with 60 days of growth (DM = 18,76) and chopped in a stationary forage-chopper. After processing, the grass and the PC were mixed in the previously defined proportions and packed in plastic buckets (15 L), containing sand in the bottom to quantify the effluent losses (average packing density = 707.00 ± 37.14 kg/m³ of NM). After the period of 33 months of storage, the silos were opened, and a sample was taken for analyzing the chemical composition. Subsequently the contents dry matter (DM), mineral matter (MM), organic matter (OM), crude protein (CP), neutral detergent fiber corrected for

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ash and protein (apNDF), acid detergent fiber (ADF), hemicellulose, cellulose, and non-fibrous carbohydrates (NFC) were evaluated. Data were submitted to ANOVA and linear regression analysis by using the GLM and REG procedure of SAS(α=0.05), considering the fixed effect of PC and the random error in the model.

Results and Discussion: The inclusion of the PC promoted a linear increase (P < 0.05) in the DM, OM, CP, EE, HEM and NFC contents of the ensiled mass. However, there was a linear decrease in the levels of ASH, apNDF, ADF and CEL. The DM content of the silages increased 0.62% for each 1% of PC inclusion. The increase of the DM content is justified by the addition of the by-product (that in this study presented 89.61 % DM). The same occurred with the contents of EE and NFC. The increase of the NFC provides an increase in the nutritive value of the silage, besides being substrates of bacteria of the genus Lactobacillus that make a desirable fermentation in the silage. The inclusion of PC also contributed to the linear growth of organic matter and consequent decrease of ASH. The content of apNDF showed behavior possibly due the FNC content of the PC (21.68%), that is higher than the concentration found in elephant grass (16.80%), so the addition of PC increases the concentration of FNC and consequently, as an additive decreases the apNDF values of the mass. The ADF levels reduced, however, the highest values were found in the silages with lower inclusion of PC (0 and 7%), which presented lower DM, since these could have suffered a greater loss by effluent of the soluble components, increasing in this way the components of the fibrous fraction. The cellulose contents presumably decreased because PC has lower concentration of cellulose than elephant grass.

Conclusions: Addition of patauá cake in elephant grass silage modifies the chemical composition, by increasing the non-fibrous carbohydrates, which can improve the nutritive value of elephant silages. This effect is considered consistent because was marked even after 33 months of storage.
MILK PRODUCTION OF DUAL-PURPOSE COWS WITH ACCESS TO AN ASSOCIATION OF LEUCAENA LEUCOCEPHALA AND CYNODON NLEMFUENSIS

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Keywords: fodder quality, Leucaena, milk production.

Introduction: Livestock production in tropical regions of the world faces serious limitations related with the quality and availability of forage resources, included the consequences of climate change. Animal performance such as the rate of live weight gain and milk production level depends on the nutritive value of forage, which is also related to the year, season and the stage of maturity of the swards being grazed. One alternative to the improve grazing systems based on grass monocultures is to associate a leguminous species with the grass in order to take advantage of nitrogen inputs from N₂ fixation by the legume in order to pasture production and forage quality. The aim of this study was to evaluate fodder intake and milk production of dual-purpose cows with access to an association of Leucaena leucocephala and Cynodon nlemfuensis.

Material and methods: The experiment was carried out on the dairy research farm at the Faculty of Veterinary Medicine and Animal Science, University of Yucatan, Mexico. Twelve multiparous Holstein × Zebu cows with an average weight of 498 ± 52.5 kg and a body condition of 4.1 ± 0.50 (where one was emaciated, nine were obese) were used. The cows were divided into 2 homogeneous groups to the following treatments: control (CT), cows supplemented with commercial concentrate feed (4.31 kg ± 0.66 dry matter [DM]/cow/d) +18 h grazing in Stargrass; and Leucaena treatment (LT), cows supplemented with commercial concentrate feed (4.19 ± 0.57 kg DM/cow/d) + 18 h grazing in an association of Leucaena/Stargrass. Forage availability from the two treatments were assessed just before animal grazing. Five samples were taken from each paddock on each occasion. Subsamples of grass and Leucaena were selected and oven-dried at 60 ºC to constant weight. Forage samples were analyzed for crude-protein (CP) by the Dumas method. Fodder intake was also recorded, from the difference, between the forage availability and the forage residual. Milk yield and quality was recorded for 12 days. A

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completely randomized design with 2 treatments was used. Fodder intakes was analyzed by the general linear model (GLM) procedure. Milk yield values were analyzed as repeated measures by the MIXED procedure with an autoregressive structure of covariance. Systems were the fixed effects and the cows the random effects. Body condition score was analyzed using the non-parametric test of Mann-Whitney.

**Results and Discussion:** The availability of Stargrass was greater (3057.0 ± 2039.8 kg DM/ha) than the association of Stargrass + *Leucaena* (2093.4 ± 816.6 kg DM/ha). The chemical composition and availability of Stargrass were within the expected ranges for tropical pastures. However, the crude protein (CP) of Stargrass and *Leucaena* were both above (259.41 g CP/kg DM) the minimum to meet the requirements of rumen bacteria. The CP of *Leucaena* (26.7%) was higher than that reported elsewhere for *Leucaena* forage (22.03%), but lower than that reported for *Leucaena* leaf meal (29.2%). The animal fodder intake of Stargrass was 11.64 ± 4.21 kg DM/animal/day, while the association of Stargrass + *Leucaena* was 10.82 ± 3.87 kg DM/animal/day. On the other hand, milk yield and composition were similar for both systems (8.8 kg/animal/day for Stargrass monoculture; 8.14 kg/animal/day for the association of Stargrass + *Leucaena*) respectively. Milk CP content range from 3.08% – 2.97%; lactose 4.57% - 4.42% and fat content 4.02% - 3.62% for Stargrass and the association of Stargrass + *Leucaena*, respectively.

**Conclusions:** The association of *L. leucocephala/C. nlemfuensis* provides a more balanced diet to animals due to higher crude protein content which also can replace part of the concentrate without detrimental effects on milk production and reproduction of dual purpose cows.
CHEMICAL COMPOSITION FROM SILAGE OF WET WASTE OF BREWERY WITH INCLUSION LEVELS OF SOYBEAN HULLS

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Keywords: soybean hulls, ensilage, WWB

Introduction: The utilization of agro-industrial by-products in silage could increase nutritional efficiency and, consequently, increase weight gains and reduce costs. Among the alternative sources, stands out the wet waste of brewery (WWB) with nutritional value and potential for inclusion in animal diets, because it is characterized as bulky: protein. Coming from brewing, at the end of this industrial process, beyond the final product, there is a considerable volume of WWB. Soybean hulls (SH), a byproduct of soybean oil extraction, is another interesting agroindustrial ingredient for use as animal feed. Considered bulky:concentrated, because it has the physiological function of plant fiber (pectin) and energy. WWB silage with SH can be an economical alternative for being by-products available, with low acquisition value and due to their nutritional properties provide animal growth performance. The objective was to determine the chemical composition of WWB silage with inclusion of increasing SH levels.

Materials and methods: The study was conducted in the Experimental Farm of the Federal University of Amazonas, located at the 922 km of the BR-174, Manaus/AM. Consisting with increasing four SH inclusion levels: WWB silage SH 0%, WWB silage + 15% SH, WWB silage + 25% SH, and WWB silage CS 35% SH, with three replicates. The material was stored in experimental silos made of PVC (10 cm in diameter x 50 cm deep), with and approximate capacity of 4 kilos of silage each. After filling and compacting the silos, they were sealed for 30 days. After that the silos were opened for analyses. The chemical composition analyses were conducted in the Forragicultura e Pastagens Laboratory at UFAM. The parameters evaluated were the concentrations of Dry Matter (DM), Crude Protein (CP), Ether Extract (EE), Organic Matter (OM), Mineral Matter (MM), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Hemicellulose (HEM), Total Carbohydrates (TC), Non-fiber Carbohydrates (NFC), Total Digestible Nutrients (TDN). The data were
evaluated by means of analysis of variance and regression of the polynomial type through the SISV AR program at a 5% probability level.

**Results and discussion:** Each inclusion, the addition of SH in WWB silage increased (P < 0.05) the contents of DM and ADF being the treatment with inclusion of 35% presenting the percentage values 43.76 and 29.28%, $\hat{y} = 20.994 + 0.6182 \times SH$ ($r^2 = 0.98$) and $\hat{y} = 16.798 + 0.4016 \times SH$ ($r^2 = 0.92$) respectively. For the EE, HEM and TND, there was a decreasing effect with the inclusion of SH, 9.08% to 5.49%, 32.00% to 21.28% and 76.18% to 63.92%, $\hat{y} = 8.9518 - 0.1010 \times SH$ ($r^2 = 0.99$), $\hat{y} = 29.797 - 0.2759 \times SH$ ($r^2 = 0.66$) and $\hat{y} = 76.259 - 0.3656 \times CS$ ($r^2 = 0.98$) respectively. There was an increase in NDF and ADF levels from 48.32 to 53.35% and from 16.33 to 29.28%, $\hat{y} = 46.014 + 0.1938 \times SH$ ($r^2 = 0.40$) and $\hat{y} = 16.798 + 0.4016 \times SH$ ($r^2 = 0.92$) respectively. The 0% SH inclusion level showed a higher percentage of total losses. Once the WWB is characterized by low content of DM, which makes it difficult to compaction, it promotes a higher pH variation, impairing silage quality. However, the inclusion of CS in RUC raises the MS content favoring the conservation of the ensiled material, reducing the production of contaminating effluents and losses of important soluble compounds in animal nutrition with preservation of total carbohydrates.

**Conclusion:** The level of SH inclusion linearly reduced the acidity of the silage. Total losses decreased as the SH inclusion increased to the WWB. The inclusion of 35% SH in the WWB promoted desirable pH and DM values.
Cluster Analysis Based on Morphogenetic Data in Genotypes of Panicum Maximum

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Keywords: appearance, elongation, structure, tocher.

Introduction: When considering pasture as the main source of food for ruminants, the processes of diversification and management become essential for the success of the productive chain. In this context, the use of methods that contribute to the knowledge of management requirements before the launch of new cultivars have the potential to optimize and direct the selection process. The use of morphogenesis associated with genotype grouping analysis allows the study and simplified characterization of the individuals according to the morphogenetic profile of the plant. The aim of this study was to form morphofunctional groups based on morphogenic and structural characteristics through the clustering of Tocher Optimization in Panicum maximum genotypes.

Material and methods: Seventeen genotypes (B57, B53, T97, T104, G56, K5, 309, A78, T110, 217, B46, C12, B11, H64, C53, B55, K214) were evaluated in a randomized complete block design with three replicates. The variables estimated were: leaf appearance rate (LAR), phillochron (PHI), leaf elongation rate (LER), leaf senescence rate (LSR), number of live leaves (NLL), leaf life spam (LLS), stem elongation rate (SER), leaf:stem ratio (LSR), number of tillers (NTI) and leaf final length (LFL). Based on the estimated genotypic values, the data were standardized and used to estimate the Mahalanobis distance, used to perform the cluster analysis by the Tocher Optimization method. After the grouping, the individuals of the groups were evaluated to study the morphofunctional characterization of the groups.

Results and Discussion: After the grouping, five groups were formed, consisting of G1- (217, A78, B11, B46, B53, B55, B57, C12, G56, K214, K5, T104, T97) (309), G3- (C53), G4- (T110) and G5- (H64). The groups that presented higher values of LER were groups 3, 5 and 1. LER is directly related to the production of forage, therefore, these groups indicate great

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potential for the increase in the production of quality fodder. For SER, group 2 was highlighted, followed by group 5. SER isn’t a trait requested in forage plants, because the stem concentrates most of the plant’s lignified compounds, reducing the digestibility of the forage consumed. Group 3 resented higher values for LFL associated with high LER, evidencing potential for increased leaf production, when we have high leaf area index higher is photosynthetic rates. The NTI was fundamental for the separation of group 4, and it can be considered a characteristic with great potential to be inserted in the evaluations of the genetic improvement of forages, since from the population density of tillers it is possible to estimate the forage productive potential.

**Conclusions:** Due to the large amount of data generated from the evaluation of the morphogenic characteristics, the formation of distinct morphofunctional groups is of great value in the genetic selection process, because it facilitates the interpretation of the results and the selection of groups or individuals that obtained better performance in the evaluation.
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CRUDE PROTEIN, AMMONIACAL NITROGEN AND
PH OF SUGARCANE SILAGE WITH DIFFERENT
LEVELS OF INCLUSION OF CRAMBE BRAN

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Mariane Ferreira³, Angelo Arcanjo² and Ângela Lana¹

Keywords: adsorbent additive, chemical composition, Crambe abyssinica
Hoechst.

Introduction: The seasonality of forage production is one of the greatest
challenges of brazilian cattle raising. There is great oscillation of forage
production between different seasons of the year (dry and rainy), causing the
production to be uneven, characteristic is extremely unfavorable, since, animal
production systems have a characteristic demand profile and defined throughout
the year. Sugarcane silage presents itself as an alternative to this period of
scarcity. However, it has limitations on the final quality of the roughage. Crambe
bran (FC), as an additive with a high crude protein content, increases the quality
of sugar cane silage, thus improving its nutritional contribution.

Material and methods: This experiment was conducted at the Experimental
Farm of Moura, belonging to UFVJM, located in the Municipality of Curvelo-
MG. The data were analyzed in a completely randomized experimental design,
in a 4 × 4 factorial arrangement, with four levels of addition of crambe (0, 5,
10 and 20%, based on natural matter) and four opening times (10; 20, 30, 60
days after the preparation of the experimental silos), each with four replicates.
The material was cut, minced in a stationary chopper, in particles of 1 cm to
2.5 cm, and ensiled in 64 mini-silos, made with PVC pipes. The inclusion
of crambe meal (FC) was performed by mixing 5, 10 and 20% to sugarcane,
based on the natural matter, prior to ensiling. In the silos filling, the forage was
compacted with a wooden socket up to a density of 600 kg / m³. At the time of
opening of the silos, a sample was taken that was dried in an oven of 55ºC. The
pre-dried sample was milled with 1 mm sieve for further determination of PB,
hydrogenation potential (pH) and N-NH₃, according to literature. Statistical

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analysis of the data was performed using the SISVAR program and the results were submitted to regression analysis.

**Results and Discussion:** For PB analyzes, there was an interaction effect between the treatments studied. The inclusion of FC resulted in an increase in PB contents of the experimental silages of approximately 6.97; 10.87 and 15.78% PB for treatments 5; 10 and 20%, respectively. The CP levels obtained by inclusion of FC were higher than the 6% reported in the literature as minimum levels so that this nutrient is not limiting for the fermentation of the structural carbohydrates by the microbial flora of the rumen. The interaction between doses and times resulted in an increase in ammoniacal nitrogen content for treatments with 10 and 20% inclusion of FC. The control treatments and 5% of the addition of the FC showed a slight increase of N-NH₃ until the 30th day of opening, being observed a reduction of the content of this variable in the treatment with 60 days after ensiling. These results suggest that the addition of FC in higher amounts (10 and 20%) provided a high nitrogen availability in the ensiled mass, which resulted in a higher conversion profile of the crude protein in N-NH₃, a fact that was minimized when comparing the conversion profile observed with inclusion levels 0 and 5% of FC. The interaction effect observed for the pH variable showed higher values with the inclusion levels of the additive and lower as a function of the opening time of the silos. For the control treatment, it was observed a linear behavior, already for the treatments with inclusion of the additive there was a quadratic behavior. This difference in behavior occurred due to the addition of crambe meal (FC) in the ensiled mass. The addition of this co-product had a buffer effect on sugarcane silage, which was higher as the inclusion level was increased in the ensiled mass.

**Conclusions:** The addition of crambe bran in sugarcane silage improved its chemical-bromatological composition, indicating its inclusion in up to 10%, since larger inclusions lead to an unfavorable increase of the ammoniacal nitrogen and it functions as a buffer effect in the reduction of the pH.
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POTENTIAL HYDROGENATION, DRY MATTER AND CRUDE PROTEIN OF MARANDU-GRASS SILAGES WITH DIFFERENT LEVELS OF INCLUSION OF BANANA PEEL HAY

Gabriel Santos Souza David¹, Orlando Filipe Costa Marques², Eleuza Clarete Junqueira de Sales³, Flávio Pinto Monção⁴, Dhácomo Diorgini Dourado de Morais¹, Jessica Rodrigues de Almeida¹

Keywords: banana peel, crude protein, dry matter, hydrogen potential, silage

Introduction: The conservation of roughage as silage is an important alternative to guarantee the feeding of the herd throughout the year. The use of Brachiaria brizantha cv. Marandu, the most cultivated forage in Brazil for silage production, can be an interesting alternative due to the high production of biomass per area. However, tropical grasses usually present high moisture content (over 75%). In this sense, it is necessary to use additives with high dry matter content in order to reduce the moisture of the ensiled material, besides improving its nutritional value. Thus, the objective of this work was to evaluate the potential hydrogenation (pH), dry matter (DM) and crude protein (CP) of silages of Brachiaria brizantha grass cv Marandu with inclusion levels of banana peel.

Material and methods: The experiment was carried out at the State University of Montes Claros, Janaúba-MG campus. The banana peel was pre-dried in the sun to be used as an additive. The experimental treatments consisted of silage of Brachiaria brizantha grass cv. Marandu with four inclusion levels of banana peel (0, 10, 20, 30 and 40% in the natural material) during silage, with 8 replicates each treatment, arranged in a completely randomized design. The Brachiaria grass was collected in the pasture area of Experimental Farm of the UNIMONTES. The material was harvested and ground with forage harvester coupled to the silage tractor, the machine knives were set to particle size of 1.5 cm. After the grinding, five piles were formed in which the banana peel was added in the respective proportions and homogenized. The resulting material was ensiled in PVC tubes fitted with a “Bunsen” type valve, sealed with adhesive tape and then weighed. The silos were opened 60 days after filling,

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and samples were taken for analysis of pH, DM and CP. Data were submitted to analysis of variance and, when the “F” test was significant, inclusion levels of banana peel were submitted to the regression study (P < 0.05), by means of SISVAR program.

Results and Discussion: The inclusion of banana peel during silage resulted in higher DM contents (P = 0.0016) of ensiled material, showing increasing linear effect, with increase of 0.65 percentage points for each percentage unit of peel added, due to the higher DM content of the peel (Y = 28.76 + 0.65 * X^2; r² = 0.87). High levels of DM (above 42%) may impair compaction of the material. There was a quadratic effect for pH (P = 0.0122) due to inclusion of different levels of banana peel in the silage of marandu-grass (4.649-0.0321*X + 0.000848*X^2; r² = 0.97), with a lower pH value at inclusion level of 18.89%, possibly due to the higher production of lactic acid associated with an adequate DM content. There was no significant effect (P = 0.1402) of inclusion levels of banana peel in grass silage on CP content.

Conclusions: In order to improve the fermentation of the marandu-grass silage, it is recommended to include 18.89% of banana peel, verifying lower pH contents associated with adequate DM contents, without affecting the CP content.
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MORPHOGENETIC AND STRUCTURAL CHARACTERISTICS OF *PANICUM MAXIMUM* CULTIVARS, MANAGED UNDER ROTATIONAL STOCKING

Mateus José Inácio de Abreu¹, Cássia Aparecida Soares Freitas², Priscila Dornelas Valote³, Domingos Sávio Campos Paciullo⁴, Carlos Augusto de Miranda Gomide⁴, Mirton José Frota Morenz⁴

**Keywords:** grazing, leaf elongation rate, senescence, stem elongation rate

**Introduction:** Understanding the growth dynamics of new forage cultivars is fundamental to support the elaboration of pasture management protocols. Recently introduced forage grasses such as BRS Zuri and BRS Quênia have a promising future for pasture animal production, but require detailed studies on the leaf growth traits and shoots which may be important in developing appropriate strategies of grazing management. The present study aimed to evaluate the morphogenetic and structural traits of *Panicum maximum* cvs. BRS Zuri and BRS Quênia, during the rainy season of two consecutive years.

**Material and methods:** The experiment was carried out at Embrapa Dairy Catlle, in Coronel Pacheco, MG, Brazil, on pastures of *P. maximum* cvs. BRS Zuri and BRS Quênia, divided into 830 m² paddocks and managed under rotational stocking. The experimental design was randomized blocks into subdivided plots scheme, with three replications, where the cultivars were allocated in the plots, and the years, in the subplots. Morphogenetic and structural variables were evaluated during the period of greatest rainfall in the region (January-March), during two years (2017 and 2018). For this, three tillers were marked per clump and two clumps per replication (paddock). From the length of expanded, emergent and senescent leaves and from the length of stems, it was possible to calculate the leaf elongation rate (LER - mm/tiller/day), leaf appearance rate (LAR – leaves/tiller/day), stem elongation rate (SER - mm/tiller/day), leaf senescence rate (LSR - mm/tiller/day) and phyllochron (days/leaf). It was also possible to calculate the leaf length (LL - cm), the leaf life span (LLS - days) and the number of total (NTL) and live (NLL) leaves per tiller. The data were submitted to analysis of variance, with the aid of the

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statistical program SISVAR, to verify the influence of the cultivar, year and their interactions. The estimated averages were compared with Tukey’s test at 5% of probability.

**Results and Discussion:** The LER was influenced (P < 0.01) by cultivar x year interaction. For BRS Zuri there was a difference between years (98.9 x 133.6 mm/tiller/day, for the first and second years, respectively), while for BRS Quênia there was no year effect (mean value of 107.3 mm/tiller/day). The Zuri cultivar presented higher LER than Quênia in the second year (133.6 x 104.9 mm/tiller/day), but no difference was observed between cultivars in the first experimental year. As a consequence of the higher LER, especially in the second year, the Zuri presented larger leaf blades (P < 0.01) when compared to Quênia (92.1 x 79.1 cm, for Zuri and Quênia, respectively). There was no significant effect (P > 0.05) of the factors studied on the variables LAR, phyllocron and LSR, which presented mean values of 0.1279 leaves/day, 8.64 days/leaf and 1.52 mm/tiller/day, respectively. The SER varied (P < 0.01) only with the cultivars. BRS Quênia presented higher SER (6.93 mm/tiller/day) than BRS Zuri (3.50 mm/tiller/day), which can be attributed to its early flowering, still in late summer, which induces the stem elongation. The LLS was higher (P < 0.05) in the second (47.9 days) than in the first (42.5 days) year. For the NTL and NLL no significant effects of the factors studied were observed, with mean values of 5.82 and 5.61 leaves/tiller, respectively.

**Conclusions:** The similarity in the most of morphogenetic rates and structural traits reveals that the cultivars show similar growth dynamic. However, the BRS Zuri stands out for the higher leaf elongation rate and BRS Quênia for the more intense elongation of stems. Management strategies that contribute to the elimination of the apical meristem in BRS Quênia in the mid-summer may control the accentuated stem elongation, favoring the pasture structure.
FERMENTATION LOSSES AND DRY MATTER RECOVERY OF MARANDU GRASS SILAGE WITH DIFFERENT LEVEL OF BANANA PEEL PRE-DRIED

Orlando Filipe Costa Marques¹, Eleuza Clarete Junqueira de Sales², Flávio Pinto Monção³, Alisson Júnior Moura Alves Barroso⁴, Maria Catiane Araújo Silva Veloso¹, João Paulo Sampaio Rigueira²

Keywords: effluents losses, by-products, recovery of dry matter, additives.

Introduction: The tropical grasses have the characteristic of the biomass production in the rainy season but in the period of the droughts these have low productivity due to the edaphoclimatic conditions leading to the deficit of food to the herds in this period. One way of conserving the production surplus of the grasses to provide to the herd in the period of scarcity is to ensilate this material, however, the biomass of the forage grasses in general presents a high moisture content, which can disrupt the silage fermentation process leading to significant losses of the ensiled material. One way to reduce these losses is to use moisture-sequestering additives, where corn or sorghum crumbs or by-products as soybean or fruit processing residues can be used. Therefore, the objective of this work was to evaluate banana peel levels in brachiaria grass silage in the reduction of losses during fermentation and dry matter recovery.

Material and methods: The experiment was carried out at the State University of Montes Claros, Janaúba MG, located at 15° 52’38” South and 3° 20’05” West. The treatments consisted of silage from Brachiaria brizantha cv. Marandu with five inclusion levels of banana peel (0, 10, 20, 30 and 40% inclusion in natural matter). A completely randomized design was used, with five treatments with 8 replicates. The banana peel was pre-dried (88% dry matter) and the Brachiaria grass was collected in the UNIMONTES’s Experimental Farm. The material was harvested (10 cm from the soil) after 60 days of regrowth and ground to 1.5 cm with forage harvester for ensiling. After grinding the banana peel additive was added in the respective proportions and homogenized. For silage were used PVC silos of known weight, 50 cm long and 10 cm in diameter. At the bottom the silos contained dry sand separated from the forage by foam for quantification of the produced effluent. The forage was added to the

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silos and compacted (500 kg material natural/ m³). After filling, the silos were closed with PVC caps fitted with “bunsen” valves, sealed and then weighed. The opening occurred 60 days after silage. The dry matter losses in the silages under the gas and effluent forms were quantified by weight difference. Data were submitted to regression analysis (P < 0.05).

**Results and Discussion:** There was a quadratic effect on the different levels of banana peel inclusion for the variables gas losses (P = 0.0016) and DM recovery (P = 0.0016), with the equations $Y = 12.52 + 0.41 \times X - 0.013 \times X^2$ ($r^2 = 0.87$); $Y = 87.47 - 0.41 \times X + 0.013 \times X^2$ ($r^2 = 0.87$), respectively. The inclusion of banana peel did not change the effluent losses (P = 0.5362), with an average of 1.91 kg / t of green matter. The lowest loss of gases and high recovery of the dry matter was verified at the level of 16.03% inclusion of the banana peel. The inclusion level of 16.03% of banana peel in the *Brachiaria* silage had the lowest loss by gases and effluents, these smaller losses occurred by the supply of soluble carbohydrates of the banana peel that provided substrate for the homofermentative and heterofermentative bacteria for synthesis of lactic acid and acetic acid inhibiting the action of clostridial bacteria, thus decreasing the losses and occurring a greater recovery of dry matter.

**Conclusions:** The inclusion of 16.03% of pre-dried banana peel in the *Brachiaria* ensilage reduces gas losses and maximizes dry matter recovery.
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SOLUBLE CARBOHYDRATES OF SUGARCANE SILAGE WITH DIFFERENT LEVELS OF INCLUSION OF CRAMBE BRAN

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Keywords: additive, conservation, co-products

Introduction: Sugarcane is an important crop to reduce the impacts of seasonality of forage yield, widely used to supply the food deficit in livestock during the dry period of the year. Silage is an alternative to rationalize the use of sugarcane as a bulky food in the dry season. Although sugarcane is a bulky option in livestock, it is necessary the use of additives to reduce losses during the silage. In the search for additives to be included in the silage process, the agro-industry co-products have attracted interest from researchers and cattle ranchers. Crambe bran (CB) is a co-product of the crambe oilseed (Crambe abyssinica Hoehst), obtained after the extraction of biofuel from this plant. Because it has absorbent properties, it has been used in animal feed, especially in the nutrition of ruminants. The objective of this study was to evaluate the effects of the inclusion of crambe meal on the soluble carbohydrate content of sugarcane silage.

Material and methods: This experiment was conducted at the Experimental Farm of Moura, belonging to UFVJM, located in the Municipality of Curvelo-MG, using the cane cultivar RB867515 at 14 months of age. The data were analyzed in a completely randomized experimental design, in a 4 × 4 factorial arrangement, with four levels of addition of CB (0, 5, 10 and 20%, as feed) and four opening times (10; 30, 60 days after the preparation of the experimental silos), with four replicates each. The material was manually cut in the field, without suffering shambles, chopped in a stationary chopper, in particles of 1 to 2.5 cm and 64 silage in laboratory silos, made in PVC tubes. The CB inclusion was performed by mixing 5, 10 and 20% to the sugarcane, based on the natural matter, prior to ensiling. At the filling of the silos, the forage was compacted to the density of 600 kg / m³. Soluble Carbohydrate Content (CHOs) was evaluated according to the methodology of literature. A sample previously processed (dried in an oven ventilated at 55°C and ground in a 1mm sieve)

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is subjected to extraction of the soluble carbohydrates by means of an 80% alcoholic solution and acid solution prepared with anthrone and then read in a spectrophotometer using a solution of glucose to prepare the standard curve. Statistical analysis of the data was performed using the SISVAR program and the results were submitted to regression analysis.

**Results and discussion:** The response was more evident at 10 days of opening, with a decrease of 7.95; 8.09 and 9.24% of the CHOs content for the 5, 10 and 20% CB addition levels respectively, relative to the control treatment. For the control treatment there was a 16.91 decrease; 5.93; 3.4 and 0.19% CHOs for the 0-10, 10-20, 20-30 and 30-60 silage days, respectively, similar behavior for the additive silages. The decrease for all treatments was higher until the 30 days for opening of the silo, after which the curve remained stable. The reduction in the soluble carbohydrate content during the opening times occurred due to the lower losses of DM for the treatments with inclusion of the absorbent residue, where there was an increase of dry matter, proving that these treatments are more efficient in reducing the loss of CHOs in silage.

**Conclusion:** It is indicated inclusion of up to 10% of crambe meal in sugarcane silage. From this there occurs reduction of soluble carbohydrates.
MICROBIOLOGICAL DYNAMICS AND PH AT THE OPENING OF GROUNDCORN GRAIN SILAGE REHYDRATED WITH WATER OR WHEY

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Keywords: conservation, corn, microorganisms, whey

Introduction: Among the corn processing techniques in Brazil for ruminants, the silage of ground and rehydrated corn grains consisted in the conservation, in an acid environment, of anaerobic form. The use of whey in rehydration can improve storage parameters in ground and rehydrated corn grain silage. The aim of this study was to evaluate the use of whey in the rehydration of corn grain for ensiling with the use of inoculant.

Material and methods: The experiment was conducted at the Federal Southeast Institute of Minas Gerais, Rio Pomba. Using the completely randomized design in a factorial scheme (2x2x6) with 3 replicates per treatment in repeated measures in time, the treatments were rehydrated with water or whey, with inoculant (Lactobacillus plantarum MA18/5U and Propionibacterium acidipropionici MA26/4U (3.0 x 10^5 CFU/g) or without inoculant and evaluation on days 0 (before storage), 4, 8, 16, 32 and 64. Experimental PVC silos with 0.1 m diameter and 0.60 m height were used with Bunsen type valves, ground corn (4 mm) and whey from enzymatic coagulation. Quantification of lactic acid bacteria (LAB) was performed by plating in MRS agar and the plates were incubated at 35°C for 72 hours. Enterobacteria (ENT) were determined by plating in Violet Red Bile Glucose Agar and the plates were incubated at 35°C for 48 hours. Yeasts and molds (YM) were determined by plating in Potato Dextrose Agar, acidified with 10% (w/v) tartaric acid and the plates were incubated at 25°C for 5 days. The pH was evaluated in a completely randomized design in a factorial scheme (2x2x5) with 3 replicates per treatment measures repeated in time, a digital potentiometer was used on opening days 4, 8, 16, 32 and 64. The data were analyzed in PROC MIXED of the SAS program (SAS Inst. Inc., Cary, NC), previous proof of normal distribution (Shapiro-Wilk test) and homoscedasticity of variances (Bartlett’s test) with significance level at 5 % probability.
**Results and Discussion:** It was observed that there was an interaction effect (P < 0.05) between rehydration (water and whey), inoculant (with or without) and in different fermentation periods (0 (before storage), 4, 8, 16, 32 and 64 days) on the count LAB, ENT and YM. There was also an interaction effect (P < 0.05) on pH in the openings of 4, 8, 16, 32 and 64 days. The treatments that had the lowest values of LAB, ENT, YM and pH at the opening, in the average independent of the fermentation periods, were the rehydrated with whey and inoculated, water and inoculated, with only water and only whey respectively. Despite the lower LAB count for the treatments inoculated in the mean, there was a higher pH drop in these treatments than in the un inoculated ones, and inhibition of heterofermentative LABs may occur, starting earlier in the second stage of this phase where there is a predominance of homofermentative LABs that are more efficient in producing lactic acid with a higher pH reduction potential, affecting ENT count in the first five opening times and canceling the count in the last fermentation period, with the majority of ENTs being sensitive to pH below 5. The YM count decreased over time, a justification for the reduction in the is the competition with the LAB and ENT for soluble carbohydrates, since YM are not heavily influenced by pH.

**Conclusions:** The corn grain silage ground and rehydrated with whey and inoculated reached the best parameters in microbiological dynamics and pH during opening.
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DENT CORN HYBRID DIFFERS FROM FLINT CORN HYBRID REGARDING THE CHEMICAL COMPOSITION, WHEN HARVESTED FOR SILAGE IN DIFFERENT PLANT MATURITY STAGES

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Keywords: corn silage, endosperm texture, non-fiber carbohydrates

Introduction: The corn silage is the main forage source in ruminant diets, because of its high nutritional value. To ensile whole plant corn silage (WPCS), shall be considered the nutritive value of stems and leaves, also the grain: forage ratio of the plant. In order to choose the maturity stage of the plant during the harvest and the hybrid, it must to take into account ther eduction of the low digestible neutral detergent fiber (NDF) of silage, and the maximum starch content with high digestibility. The objective of this trial was to evaluate WPCS chemical composition of three hybrids (dent, flint and semi-flint) harvested with 30% and 40% of dry matter (DM).

Material and methods: The trial was conducted at the Animal Science Department of the Luiz de Queiroz College of Agriculture, University of São Paulo (USP/ESALQ). Whole corn plants dent, flint and semi-flint were harvested between February and March of 2017, at 30% and 40% of DM and packed in lab scale silos (20L buckets). Silages were stored for 90 days. At opening, silos were sampled to measure DM, ash, NDF, ADF, CP, NFC and EE content. A silage sample was dried in forced-air oven at a 55ºC during 72h. After that, the material was ground in a knife mill until the sample pass through a 1mm sieve. It was determined the DM in a 105ºC oven during 16h, to calculate true dry matter. Ashes were obtained using a 600ºC oven during 4h. The CP analysis was determined by the Dumas method (Leco instruments INC), and the EE by Soxhlet extractor method (AOAC, 1997). NDF and ADF were analysed using sequential method of ANKON Fiber Analyser. The NFC was estimated by the equation: NFC=100-(NDF+CP+EE+Ashes). The experiment was a completely randomized design, using factorial treatment structure, three hybrids and two maturity stages. There was three replicates by treatment. The data were analyzed with the proc mixed of SAS.

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Results and Discussion: The silage harvested with theoretical maturity of 30% and 40% DM, in fact showed DM content of 30.10% e 34.17%, respectively. The ashes were influenced by the hybrid factor, and the content was 4.61%, 3.60%, 4.07% (P < 0.0001), for the hybrids flint, dent and semi-flint, respectively. There was maturity stage difference for EE (P < 0.0001) and CP (P < 0.0001), where the hybrids harvested with 30% DM (2.63% EE) had less EE than hybrids harvested with 40% DM (3.16% EE) and for the CP hybrids harvested with 40% DM had higher CP (7.18%) than 30% DM (6.47%). The hybrids flint, dent and semi-flint showed 6.87%, 7.62% and 5.98% CP (P < 0.0001), respectively. Thus, the corn hybrids had proper content of EE and CP, although the corn is not a good source of lipids and protein. However, corn silage is acknowledge as source of carbohydrates, and fibrous carbohydrates (NDF) and non-fibrous carbohydrates (NFC) are about 85% of corn silage. The three hybrids had different NFC content, but near to the expected, flint (34.41%), dent (40.69%) and semi-flint (41.05%) (P < 0.0001). Regarding NFC (P < 0.0001), NDF (P < 0.0001) e ADF (P < 0.0001) contents, there was difference between hybrids, which the dent, flint and semi-flint showed 40.69%, 34.41% and 41.05% for NFC, 45.16%, 51.24% and 45.95% for NDF and 25.50%, 28.55% and 23.58% for ADF, respectively.

Conclusions: The later maturity stage increased the lipids and protein content of the hybrids. However, the NDF, ADF and NFC contente was affected by the hybrids, where the semi-flint showed the best values.
EFFECT OF FORAGE LITTER FROM GRASS AND LEGUMES ON SOIL RESPIRATION IN A TROPICAL GRASSLAND SOIL

Abmael da Silva Cardoso¹, Darlan Marcelino de Jesus², Débora Sinischalchi¹, Robert Michael Boddey¹, Ricardo Andrade Reis¹, Ana Cláudia Ruggieri¹

Keywords: forage legumes, *Arachis pintoi*, CO₂ fluxes, Marandu-grass

Introduction: Soil respiration (ECO₂) is a key indicator of the soil management quality. Grassland and grazing management can affect soil respiration. Litter from legumes and grass have different biochemical composition and may affect ECO₂. Forage legumes can be included in different proportions in grassland. In the present study, we compared the effects of variation in the proportion of litter from forage legume and grass. Our objectives were to clarify the effects of different litter C and N rations on CO₂ fluxes in tropical grasslands, to evaluate how persist CO₂ emissions from litter and to quantify soil respiration from grasslands soils.

Material and Methods: The experiment was conducted at São Paulo State University in Jaboticabal, SP, Brazil. The treatments were different proportion of legumes and grass litter (100%, 75%:25%, 50%:50%, 25%:75% and 100%, legume and grass, respectively) with 5 repetitions in a completely randomized design. Litter from Pinto Peanut (legume) and marandu-grass (grass) was used. Soil ECO₂ was quantified using static closed chamber followed by gas chromatography determination. Data were analyzed by heterogeneity and normality followed by ANOVA. Orthogonal polynomial contrasts was run to verify the effect of variation in the proportion of legume:grass litter on soil ECO₂.

Results and Discussion: During the 102 days of evaluation CO₂ fluxes varied from 9.09 to 168.46 mg CO₂ m⁻² day⁻¹. Soil respiration was affected by the different ratio of legume and grass litter (P < 0.01). Soil ECO₂ decreased linearly that averaged 18.56, 24.73, 31.76, 34.38 and 34.17 mg CO₂ m⁻² day⁻¹. The highest fluxes were observed in the first week after litter application and were higher in this period for the treatments with more than 50% of legume litter. This could be explained by the activity of microorganisms being regulated by

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nitrogen which is limited in the high C/N ratio treatments. In the treatments with high amount of legume litter, without nitrogen limitation, the high soil respiration in the beginning decreased with time because of exhaustion of easily available carbon. Analyzing the entire experiment, soil ECO$_2$ was higher in the treatments with more grass litter because of soil N mineralized can be used by microorganism once there was no C limitation.

**Conclusion:** The results indicate that soil respiration from litter is lower when including forage legumes, then mixed pasture is a strategy to reduce CO$_2$ emissions.
EFFECT OF PASTURE MANAGEMENT WITH LEGUMES OR NITROGEN FERTILIZATION ON URINARY PARAMETERS OF DAIRY HEIFERS IN MARANDU GRASS PASTURES

Andressa Scholz Berça¹, Abmael da Silva Cardoso¹, Vanessa Zirondi Longhini¹, Robert Michael Boddey², Ricardo Andrade Reis¹, Ana Cláudia Ruggieri¹

Keywords: forage peanut, microbial protein, purine derivatives, urea.

Introduction: The rumen microbes, mainly bacteria, use ruminal ammonia N (N-NH₃) along with organic acids to synthesize amino acids for their growth. A regular growing of this microbe and their subsequent digestion in the small intestine, which is a source of protein, affect cattle maintenance, growth, and lactation. Using urinary parameters such as purine derivatives and urinary ammonia can indicate the microbial protein supply and N utilization by cattle. The inclusion of forage legumes and N fertilization may affect these parameters. The study aimed to compare microbial protein synthesis, microbial nitrogen compounds, purine derivatives, creatinine and urea of dairy heifers raised in pastures of marandu grass without N source, fertilized with urea and intercropped with forage peanut.

Material and methods: The experiment was conducted in Jaboticabal, SP, Brazil. The treatments were marandu grass without N source, fertilized with urea and intercropped with forage peanut, in a completely randomized design with seven replicates under intermittent grazing by crossbred dairy heifers, with an average weight of 300 kg. The experimental area consisted of 12 paddocks with 0.12 ha each. The criterion of grazing start was 95 % LI and a one-day period of occupation. Urine spot samples were collected in the last 5 days from two grazing cycles. The synthesis of microbial protein and microbial nitrogen compounds were estimated through the purine derivatives (PD), which include allantoin and uric acid, that were determined by the colorimetric method. Commercial kits of Analisa® brand were used to determine the creatinine concentration using the kinetic-colorimetric method and to determine the urea concentration, using the enzymatic-colorimetric method. ANOVA was performed by F test and when significant means were compared by Tukey test. Significance was declared when P < 0.05.

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**Results and Discussion:** Only urea differed between treatments (P = 0.026), which averaged 350.15, 484.02 and 721.50 mg/dL for the mixed, control and fertilized treatments, respectively. While the purine derivatives and microbial protein did not differ for the different grazing N management. Among the PD, allantoin ranged 75.44, 72.88 and 88.71 mmol/d and uric acid ranged 21.80, 15.08 and 19.85 mmol/d for the mixed, control and fertilized treatments, respectively. Microbial protein averaged 352.62, 306.90 and 411.35 and, microbial nitrogen, 56.42, 49.10 and 65.82 g/d for the mixed, control and fertilized treatments, respectively. Ruminants use mainly amino acids from microbial digestion in the intestines for their growth, maintaining and lactation. Once we did not observe differences in the production of microbial protein between treatments, differences in urinary urea excretion probably occurred due to N from the feed, which indicates that extra N from the pasture fertilized with N were not retained by the animals.

**Conclusions:** Only urinary urea was affected by the inclusion of legumes and nitrogen fertilization in pastures of marandu grass. The highest urea-N was found in the fertilized treatment indicating a reduction of nitrogen efficiency usage by the animals. Once urea is the main source of N pollution in pastures, the inclusion of legumes can be a strategy to mitigate N losses for the environment.
GRAZING INTENSITY OF MARANDU GRASS IN SILVIPASTORAL SYSTEM

Róberson Machado Pimentel¹, Dilermando Miranda da Fonseca², Manoel Eduardo Rozalino Santos³, Fernanda Helena Martins Chizzotti², Geraldo Fábio Bayão⁴, Daiana Lopes Lelis²

Keywords: grazing management, organic reserves, post-grazing residue

Introduction: The productive success of silvopastoral systems basically depends on optimized interaction of tree density and arrangement on the growth of pasture. This shaded environment grasses have adaptive response with anatomical and physiological changes, consequences of microclimate changes that can lead to profound changes in productivity and sustainability of forage. Thus, despite the silvopastoral systems represent an alternative technology in livestock production, microclimate variations on these systems still have difficult the development of more appropriate management practices to forage in the understory. Thus, the study was conducted in order to quantify the changes in productivity and compounds of reserves marandu grass pastures managed in two heights of post-grazing residues in silvopastoral systems under intermittent stocking.

Material and methods: The experiment was conducted in the area located on the campus of the Federal University of Viçosa. Treatments consisted of two grazing intensities (15 and 21 cm) in marandu grasses (Brachiaria brizantha ym. Urochloa brizantha) in combination with two arboreal spacings (12x2 and 12x4 m, correspond to 65 and 55% of shade respectively) of eucalyptus clone (Eucalyptus grandis x Eucalyptus urophylla) plus marandu grass monoculture with post-grazing residue of 15 cm, adopted as a control. The variables analyzed were the mass and accumulation of forage, as well as total non-structural carbohydrates content in the root and base of stem of the marandu grass. The design was a randomized block design with three replications and data grouped by season, considering the 2 x 2 + 1 factorial scheme. The comparison of averages in the factorial was performed using the Tukey test, adopting the significance level of 5% and to compare the control treatment with the others, the Dunnet test was used with significance level of 5%.

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**Results and Discussion:** The highest values of mass and accumulation rate observed in monoculture pastures are due to the higher luminosity in this environment in relation to the shaded grasses. Among the silvopastoral systems, plants with higher height of post-grazing residue had higher forage accumulation rates during the summer season (60 vs 30 kg/ha/day), due to the greater remaining leaf area that contributes to the rapid recovery of positive carbon balance. Regarding the reserve carbohydrates the differences between the treatments were most significant at the base of the stem than in the roots. The monoculture pasture presented the highest levels of reserve carbohydrates in the base of the stem in comparison to the shaded forage, due to the greater amount of light that stimulates the formation of sugars in the photosynthetic process. In shaded systems, the plants with higher height of post-grazing residue had the highest carbohydrate level at the base of the stem in the seasons favorable to forage growth. In this situation, possibly the largest amount of remaining leaf area required lower contribution of the labile energy accumulated in the form of reserve carbohydrates to reestablish the formation of new leaves in the canopy.

**Conclusions:** In highly shaded silvopastoral systems the residue heights of the marandu grass should be higher than those postulated for monoculture pastures, in order to ensure the productivity and perenniality of forage plants.
SYSTEM OF IMAGE ANALYSIS IN THE DISTINCTION OF BRACHIARIA SEEDS

Camila Aparecida Lopes¹, Dayliane Bernardes de Andrade¹, Luiz Alberto Gonçalves Franco¹ and Maria Laene Moreira de Carvalho¹

Keywords: GroundEye®, seeds, visual analysis

Introduction: Analysts identify species of brachiaria seeds visually by evaluating their morphological characteristics, which leads to a subjectivity and delay of the results and many errors in the identification of the species. An alternative to improve accuracy and reduce the time spent in distinguishing brachiaria species, the image analysis technique can be used. The objective of this work was to evaluate the efficiency of image analysis in the differentiation of brachiaria species.

Material and methods: Four Brachiaria species (Brachiaria brizantha, Brachiaria decumbens, Brachiaria ruziziensis and Brachiaria hybrid) were used. The treatments were composed by the combination of the species, with mixing proportions of 1, 2, 5, 10 and 25%. The GroundEye® (version S120) captured and processed images. The CIELab color system was used in the configuration of the analysis for color calibration, with a hue index of 175.1 to 285, a saturation of 0.300 to 1,000 and a brightness of 0.00 to 1.00. The minimum seed size was set at 0.0100 cm² and the minimum separation distance was 0.0050 cm. Two artificial intelligence tools were used for better separation of species: classifiers and decision network. Classifier training was performed automatically and the characteristics of seed shape, size, color and texture were determined for species identification. The final results were measured by the level of accuracy in the identification, in each sample analyzed, comparing the visual analysis with the one obtained by the image analysis.

Results and discussion: The correctness of the image analysis for the differentiation of brachiaria species was approximately 94%. The analysis performed using the GroundEye® system was more accurate when the mixing ratios between the species were higher (10 and 25%). The samples with the combinations using Brachiaria hibrida were the ones with the highest average analysis errors when compared to the others, probably because Brachiaria hibrida was the cross of four species, including Brachiaria brizantha and

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*Brachiaria ruziziensis*, and inherited morphological characteristics of the species that participated of the crossing.

**Conclusions**: A 94% accuracy level was obtained in the identification of the different brachiaria species by the analysis of images using the GroundEye® system, being necessary adjustments for greater efficiency in the analysis. Support: CAPES, CNPq, Fapemig.
BRACHIARIA SEED STORAGE IN DIFFERENT ENVIRONMENT CONDITIONS

Janaína Guarieiro Ribeiro de Assis¹, Diego de Souza Pereira¹, Thaísa Fernanda Oliveira¹, Márcio do Carmo¹, Maria Laene Moreira de Carvalho¹ and Renato Mendes Guimarães¹.

Keywords, germination, refrigerated, storage, viability

Introduction: The quality of seed is crucial to the success of pasture formation. Storage is a basic practice in the control of the physiological seed quality and is a method through which the viability of the seeds can be preserved and their vigour kept at a reasonable level during the time between planting and harvesting. The ability of the seeds to maintain their quality during storage is influenced by several factors, including water content when the seeds were stored, the temperature and relative humidity of the air in the storage environment, and the packaging used for preserving the seeds. The seeds treatment by fungicides has been used as an important tool in pathogen control during storage. This work aimed to evaluate the tetrazolium viability of Brachiaria seeds stored in different environments to ensure their conservation.

Material and methods: The seeds of Brachiaria hybrid cv. Mulato II were treated with Maxim XL fungicide at 250 mL/100 kg seeds were used before the storage. Were evaluated the effect of different seed lots and storage environment over 18 months (0, 90, 180, 270, 360, 450 and 540 days). The seeds were stored in refrigerated room (10 °C) or in conventional warehouse (25°C - 30 °C) and was used 4 lots of seeds. The seed quality was evaluated using the tests of germination and viability. A completely randomized experimental design was used with three random replications with 100 seeds and the treatment design was a 4x7x2 factorial with factors: four seed lots and seven periods and two storage environment and seven periods. The data were subjected to an appropriate factorial analysis of variance (ANOVA), the regression analysis was performed and comparison of means tests.

Results and Discussion: A significant increase in germination percent was observed above 70% as from 90 storage days to the 3 and 4 lots compared with the 1 and 2 lots that showed the lowest seed germination during storage period. Cumulatively for all the storage period, seeds stored in refrigerated room resulted in higher percent germination than the seeds stored at conventional
warehouse preserving the physiological quality of *Brachiaria* seeds. The 3 and 4 seed lots showed higher viability compared to the 1 and 2 lots. Was observed that in the refrigerated room the viability was higher than conventional warehouse. Our study indicates that the physiological seed quality may vary depending on the storage conditions, and the germination percent and/or seed viability.

**Conclusions:** The storage condition highly affects the seed germination percentage in *Brachiaria hybrid* cv. Mulato II, which increase with the duration and storage environment. The study indicated that the storage at 10°C temperature can retain seed viability for the longer period than other storage conditions and suggests it as the best/effective storage condition for the seeds of *Brachiaria hybrid* cv Mulato II.
IMPACT OF THE INTRODUCTION OF A FORAGE LEGUME OR N FERTILIZER APPLICATION ON N₂O EMISSIONS FROM BRACHIARIA PASTURES

Camila Almeida dos Santos¹, Cláudia de Paula Rezende², Robert Michael Boddey³, Rafael Monteiro Cassador¹, Segundo Urquiaga³ and Bruno José Rodrigues Alves³

Keywords: legume, fertilizer, tropical pasture

Introduction: Beef cattle excreta are a key source of greenhouse gases (GHG) in Brazil, mainly nitrous oxide (N₂O), but emission factors are still lacking to estimate disaggregated emissions from dung and urine directly deposited on tropical pastures. Hence, the objective of this study was to estimate N₂O emission factors (EF) for cattle excreta from grazed areas of Brachiaria (Urochloa brizantha cv Marandu) fertiliser, or not, with urea and mixed with Desmodium ovalifolium.

Material and methods: The experiment was carried out on pastures of brachiaria Marandu, at Itabela, Bahia. The experimental design was a randomized 3 x 3 factorial with two replicates. The main treatment corresponded to pasture management (mixed brachiaria - D. ovalifolium pasture, brachiaria pasture fertilizer with 50 kg N ha⁻¹ and without addition of mineral N), and the subplot, to the addition of excreta (urine, dung or without excreta). The excreta came from Nellore cattle present in each type of pasture. In each pasture, small fenced areas limiting to avoid animal trampling. In each three static chambers were installed to monitor N₂O fluxes. In the areas delimited by the chamber base, each excreta (1kg of dung and 1L of urine) was added according to the treatment, and the control was maintained without excreta. Gas samplings were performed every day in the first week and then every two to three days for three months. The N₂O fluxes and the emission factor were calculated from gas chromatographic analyses and N quantities of each excreta added.

Results and Discussion: The highest N₂O fluxes were quantified from urine coming from animals grazing the mixed legume-brachiaria pasture. The lowest were detected in the control. The EFs were 0.46%, 0.70% and 0.37% of the total N applied as urine, respectively for the treatments fertilized pasture.

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mixed pasture and without addition of N. In relation to dung, the EFs were 0.012%, 0.001% and 0.075% respectively for the same grazing management treatments. In all cases, the EFs were less than 2%, the default value used in the IPCC methodology for GHG inventories.

Conclusions: Urine contributes more to N$_2$O emissions than dung, and there is a need to have EFs disaggregated by excreta type.
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MORPHOGENIC CHARACTERISTICS OF TANZANIA GRASS FERTILIZED WITH INCREASING DOSES OF NITROGEN IN AM CLIMATE

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Keywords: Panicum maximum; Pasture; Forragicultura and Climatic Stations

Introduction: Brazil had growth in the rational use of pastures, making necessary to knowledge the dynamics of accumulation of biomass in pasture to preconização management practices that allow high productivity of plant and animal components and respect the ecological and physiological limits of plants forage crops. This article aims to determine the effects of nitrogen doses on the morphogenetic characteristics of Tanzania grass in different climatic seasons during the year.

Material and methods: The work was conducted at Farm school Igarapé-Áçu (FEIGA), belonging to the Federal Rural University of Amazonia (UFRA), from August 2016 to July 2017. Each plot measures 12 m², with corridors of approximately 1m between the plots. The experimental design was a randomized block design with five blocks and six treatments with nitrogen fertilizer doses 0; 100; 200; 300; 400 and 500 N/ha. year, dividing each dose into six applications during the rainiest months of the year (February, March, April, May, June and July). The applications were carried out during the cooler times of the day, or soon after the rains, to avoid leaching of the nutrient. Morphogenic evaluations of foliar appearance rate, phyllochron, leaf elongation rate, foliar senescence rate, leaf life span and stem elongation rate were performed. The data were analyzed using the PROC MIXED procedure of the SAS.

Results and Discussion: Even though the result was not more expressive, the season was very rainy, but still presented superior results compared to low rainfall. Thus, it is observed that nitrogen fertilizing has a collaboration in the growth of Tanzania grass. In the season of many rains the results behave

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in a cubic form (P < 0.005), with values from 14.11 to 15.44 days / leaf, for the doses of 0 to 500 kg of N/ha. ano-1 which showed an increase of 8% of phyllochron regarding maximum point of 16.47 days / leaf in the dosage of 300 kg of N/ha. ano-1. The lowest dose was 200 kg of N/ha. ano-1, with a reduction of 10.3% compared to the dose with no fertilization, from the dose of 200 kg of N/ha. year-1 there was growth in the linear curve up to the dose of 400 kg of N/ha. ano-1, there being there after a further decrease. In the rainy season the TAI F results showed a behavior of the values in the cubic model (P < 0.005) with values from 2.57 to 2.97 cm/tiller/day for the doses of 0 to 500 kg of N/ha. an-1, presenting a growth of 9.1% in relation to the maximum point of 4.06 cm/tiller/day in the dose of 200 kg of N/ha. ano-1. There was an increase to the maximum point, soon after a reduction in the dose of 300 kg of N/ha. ano-1, after wards a growth up to the dose of 500 kg of N/ha. ano-1 was observed. It can be observed that the nitrogen fertilization has influence on the TAI F, having superior growth in the season of much rain if we compare between the climatic seasons.

Conclusions: The most significant morphogenic characteristics of tanzania grass are influenced by nitrogen rates and climatic seasons, exerting a positive effect on leaf emergence and elongation rates. The doses with the greatest effects in the few rainy seasons were between 300 and 400 kg of N/ha-1 N, and in the season of many rains the dose of 200 kg of N/ha-1-year had a higher effect.
SOIL RESISTANCE TO PENETRATION OF A SOIL UNDER CONVENTIONAL MANAGEMENT AND PASTURE SYSTEMS

Gislayne Farias Valente1, Crissogno Mesquita dos Santos2, Tiago de Souza Santiago3, Kessy Jhonnes Soares da Silva4, Rita Araújo de Cássia5, Ricardo Shiguereu Okumura6

Keywords: Soil compaction, Panicum maximum, physical soil incators.

Introduction: He studies about the physical quality of the soil developed significantly in the last years, justified by the concern about the compaction of the soil resulted by the alteration in the characteristics of the soil physical structure in managed areas and under pasture. The different systems of management of the soil can result in physical alterations in the soil as the formation of compacted layers and one of the most physical attributes adopted as indicative of the compacting of the soil has been the mechanical resistance of the soil to the penetration, for presenting direct relationships with the growth of the plants and for being more efficient in the measurement of the compacting of the soil. In that sense, it was aimed to evaluate the mechanical resistance of the soil to the penetration in soil under cultivated pasture and system of conventional management.

Material and methods: The experiment was accomplished at the Sítio Açaizal, located in the rural area of the municipal district of Parauapebas, Southeast area of Pará. The climate is classified as tropical humid, type Am, in the classification of Köppen, in the transition limit for AW, with index annual pluviometric around 2,000 mm. The soil was classified as Argissolo subdivided in three areas, wich was, forest area (for comparative), pasture Brizantha, and area under conventional management. There are three years that the pasture is established, having been submitted previously to the conventional planting of manioc. The area under conventional management system of the soil has historical of pasture and it was managed by soil preparation with the plow of five disks traced by a tractor 4x4. For the measurement of the mechanical resistance of the soil to the penetration (RP), the Electronic Meter of compacting of the soil was used by pressure in 17 random points for each area until the depth of 0,40 m. The results of mechanical resistance of the soil to the penetration were submitted to the variance analysis being the averages compared by the test of Tukey to 5% of probability.

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Results and Discussion: In agreement with variance analysis, only the forest area presented growing values of RP along the soil layers analyzed. Besides, it were found the smallest values of RP in comparison with the other areas until 0,20 m of depth, varying among 0,6 to 1,3 Mpa. Different from that, the deep layers among 0,30 to 0,40 m, the forest presented the highest values and it decreased in depth with value varying from 1,95 to 1,92 Mpa. When comparing RP in the pasture area and conventional tillage, it is observed that the values are differed in the layers between 0,5 m and 0,15 m, wich the pasture presents larger resistance of the soil to the penetration, however it is not characterized as compacted layer because it presented maximum value of 1,92 Mpa in the layer of 0,15 m. These results can be related to the animal trampling that commonly cause larger RP in the superficial layers of the soil. Among the layers of the soil from 0,15 to 0,25 m Rp didn’t differ among the three analyzed areas, either in the layer among 0,30 - 0,30 m. In the area under conventional management the soil presented larger RP below the depth of 0,20 m where the active organs of the implement reach in depth in the soil.

Conclusions: The RP oscillated along the layers of the soil, wich the largest depths all of the areas in study behaved in a growing way and decreased to below of the layer arable of the soil. The soil under pasture presented larger RP in the superficial layer of the soil and the forest the smallest values. The managed area presented larger RP among the layer from 0,15 to 0,25 m.
MORPHOGENIC CHARACTERISTICS OF THE MARANDU GRASS IN MIXED PASTURES WITH STYLOSANTHES CAMPO GRANDE FORMED BY DIFFERENT SOWING METHODS

Erik Kennedy de Carvalho Fonseca¹, Dawson José Guimarães Faria², Caroline Martins Gonçalves³; Maria Eduarda Eleutério Bessa¹; Gabriella Freire Adao¹; Luciene Santos de Oliveira¹

Keywords: Fabaceae, legume grass, persistence, Styloshantes capitata, Styloshantes macrocephala

Introduction: Nitrogen is the nutrient absorbed in greater quantity by the plants, and limits the development and productivity of grasses, and also exported in great quantity through animal product. Its deficiency is frequent in the Brazilian pastures, being the use of nitrogen fertilizers an alternative more common for its replacement in the system. The use of intercropped legumes with grasses in the pastures is also an alternative. However, legumes tend to disappear from the area approximately four years after the formation, and for long-term efficiency in the consortium between grasses and legumes it is essential to develop suitable practices for the establishment and maintenance of the consortium. The objective was to evaluate the morphogenic characteristics of Marandu grass mixed with the Stylosanthes Campo Grande formed by sowing methods.

Material and methods: The experiment was carried out at the IFTM - Campus Uberaba, MG, with evaluation period from November 18, 2016 to June 30, 2017, in plots of 9 m x 9 m. The grass (G) used was Brachiaria brizantha cv. Marandu and the legume (L) used was Stylosanthes macrocephala x S. capitata cv. Stylosanthes Campo Grande. Were used the completely randomized design and four replicates. The treatments consisted of four methods of seeding the consortium: 1) G broadcast seeded and incorporated deeper than the L seeds, which were broadcast seeded more superficially incorporated; 2) G and L broadcast seeded with closed grid, in alternating bands of approximately 0.80m each; 3) G and L broadcast seeded, mixing the seeds, which were incorporated with closed grid; and 4) = G single broadcast seeded and incorporated with closed grid. For the evaluation of the morphogenic characteristics, two tillers of

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G per experimental unit were used, which were evaluated twice a week. These tillers were identified with colored yarns of different colors. The length of the expanded leaves and leaves in expansion, the length of the stem and count of the number of live and dead leaves were measured. Statistical analyzes were performed using the Tukey test with a probability of 5%.

**Results and Discussion:** It was observed that sowing of grass and legume in lines presented a lower stalk length \((p < 0.05)\) than other sowing methods, with a length of 0.32 cm. day\(^{-1}\) while the others varied from 0.74 at 0.81 cm. day\(^{-1}\). Concerning the leaf elongation rate of G, there was no influence \((p > 0.05)\) on sowing methods, with a mean value of 1.14 cm. day\(^{-1}\). Sowing of grass and legume in lines resulted in leaf appearance rate (RApL) of G similar to single grass, but lower in comparison to other treatments. However, single grass presented RApL similar to the other sowing methods, except for grasses and legumes in lines \((p < 0.05)\). It was observed that the grass and legume sown in lines resulted in a higher phyllochron (15.27 days) compared to the other sowing methods that presented a mean of 9.83 days \((p < 0.05)\). The plants of the grass and legume plots sown in lines presented lifetimes of their leaves of 72.9 days \((p < 0.05)\), a higher result than the plants of the other sowing methods with a mean of 51.0 days. The senescence rate of G plants was not influenced by sowing methods.

**Conclusions:** It is concluded that the morphogenic characteristics of the marandu grass studied in this experiment are influenced by the sowing method.

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BOTANICAL COMPOSITION OF MIXED STYLOSANTHES CAMPO GRANDE AND MARANDU-GRASS PASTURES FORMED BY DIFFERENT SOWING METHODS

Caroline Martins Gonçalves¹, Dawson José Guimarães Faria², Karla Alves Oliveira³; Gabriella Freire Adao⁴; Erik Kennedy de Carvalho Fonseca⁴; Luciene Santos de Oliveira⁴

Keywords: Fabaceae, legume grass, persistence, Styloshantes capitata, Styloshantes macrocephala

Introduction: Nitrogen is the nutrient that most limits the development and productivity of forages, besides being absorbed in greater quantity by the plants, and consequently exported in great quantity through animal product. Its deficiency is frequent in the Brazilian pastures, being the use of nitrogen fertilizers the most common form for its replacement in the system. An alternative is the use of mixed legumes with grasses in the pastures. However, legumes lean to disappear from the area approximately four years after the formation, and for long-term efficiency in the consortium between grasses and legumes it is essential to develop suitable practices for the establishment and maintenance of the consortium. The objective was to evaluate sowing methods for the establishment of the consortium of Stylosanthes Campo Grande with Marandu grass, which favor the persistence of the legume in the pasture.

Material and methods: The experiment was carried out at the IFTM - Campus Uberaba, MG, with evaluation period from November 18, 2016 to June 30, 2017, in plots with 9 x 9 m. The grass (G) used was Brachiaria brizantha cv. Marandu and the legume (L) used was Stylosanthes macrocephala x S. capitata cv. Stylosanthes Campo Grande. Were used the completely randomized design and four replicates. The treatments consisted of three sowing methods of the consortium, being: 1) G broadcast seeded and incorporated deeper than the L seeds, which were broadcast seeded more superficially incorporated; 2) L and G broadcast seeded with closed grid, in alternating bands of approximately 0.80m each; 3) G and L broadcast seeded, mixing the seeds, which were incorporated

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with closed grid. Three cuts of the parcels were made on February 13, 2017, March 7, 2017 and May 12, 2017. The botanical composition was estimated by the percentage of G and L present in the forage accumulation of each cut, based on dry matter. Statistical analyzes were performed using the Tukey test with a probability of 5%.

**Results and Discussion:** The forage botanical composition was influenced ($p < 0.05$) by sowing methods, with the plots of Marandu grass and the Stylosanthes Campo Grande sown in lines, obtaining 63.42% and 36.58%, respectively, for G and L. This result is close to the desired one which is 60% for G and 40% for L, respectively. For L and G broadcast seeded, mixing the seeds, got a composition of 70.98% for G and 28.61% for L. The sowing method in which the G was incorporated more deeply than the seeds of L did not reach a percentage of L considered adequate when worked in a consortium, being its representativity in the area of only 19.65% while G presented 80.35%. The forage botanical composition of the mixed pastures had no influence ($p > 0.05$) of the evaluation periods, with results of 29.40%, 29.95% and 25.49% respectively for the first, second and third evaluation period. However, it is possible to see a propensity of L decrease from the second to the third evaluation period in the accumulated forage. This is not a desired response, since it is interesting that L persists for a long time in the pasture.

**Conclusions:** It was concluded that the highest percentage of forage legumes was obtained in the plots sown with grass and legume in lines.

**Financial Support:** FAPEMIG
FORAGE ACCUMULATION OF THE MARANDU GRASS AND THE STYLOSANTHES CAMPO GRANDE IN MIXED PASTURES FORMED BY DIFFERENT SOWING METHODS

Dawson José Guimarães Faria¹, Caroline Martins Gonçalves², Gabriella Freire Adao³, Luciene Santos de Oliveira³, Erik Kennedy de Carvalho Fonseca³, Karla Alves Oliveira⁴

Keywords: Fabaceae, legume grass, persistence, Stylosanthes capitata, Stylosanthes macrocephala

Introduction: Nitrogen is the nutrient that most limits the development and productivity of grasses, it is the nutrient absorbed in greater quantity by the plants, and consequently exported in great quantity through animal product. Its deficiency is frequent in the Brazilian pastures, being the use of nitrogen fertilizers an alternative more common for its replacement in the system. Another alternative is the use of legumes mixed with grasses in the pastures. However, it’s possible that legumes disappear from the area a few years after its formation, and for long-term efficiency in the consortium between grasses and legumes, it is essential to develop suitable practices for the establishment and maintenance of the consortium. The Stylosanthes Campo Grande is a legume that has been showing good results, being a good alternative mainly in the Cerrado, with low demand on soil fertility and high resistance to pests and diseases. The objective was to evaluate the forage accumulation of mixed pastures of Marandu grass and Stylosanthes Campo Grande formed by sowing methods.

Material and methods: The experiment was carried out at the IFTM - Campus Uberaba, MG, with evaluation period from November 18, 2016 to June 30, 2017, in plots of 9 m x 9 m. The grass (G) used was Brachiaria brizantha cv. Marandu and the legume (L) used was Stylosanthes macrocephala x S. capitata cv. Stylosanthes Campo Grande. Were used the completely randomized design and four replicates. The treatments consisted of four seeding methods of the consortium: 1) G broadcast seeded and incorporated deeper than the L seeds, which were broadcast seeded more superficially incorporated; 2) G and L broadcast seeded with closed grid, in alternating lines of approximately 0,80m
each; 3) G and L broadcast seeded, mixing the seeds, which were incorporated with closed grid; and 4) = G single broadcast seeded and incorporated with closed grid. The forage accumulation was made by cutting at 30 cm of height all the forage contained in a frame of 1 m². The samples were divided into G and L, placed in paper bags, weighed and dried in a forced circulation oven at 60ºC for 72 hours. After the samples were kept in the greenhouse, they were weighed again, obtaining the dry matter content of each sample, which was multiplied by the green weight and the result extrapolated to 1 ha. Statistical analyzes were performed using the Tukey test with a probability of 5%.

**Results and Discussion:** A higher G accumulation was observed in the sowing method that Marandu grass was more deeply sown and Stylosanthes Campo Grande was more superficially sown (2876.44 Kg. ha⁻¹) than the sowing method that Marandu grass and Stylosanthes Campo Grande were sown in lines (1675.95 Kg. ha⁻¹) (p < 0.05) and intermediate values for the method that Marandu grass was single (2754.45 Kg. ha⁻¹) and the Marandu grass seeded together with Stylosanthes Campo Grande (2322.54 kg. ha⁻¹). However, the accumulation of L per cut (mean value 873.88 kg.ha⁻¹) and total accumulation per cut (G + L) (mean value 3062.75 kg. ha⁻¹) had no influence of the sowing methods (p > 0.05). In this way we can affirm that forage production was not different for the sowing methods, that is, all methods resulted in similar forage production, even with differences in botanical composition.

**Conclusions:** It was concluded that the sowing methods of the Marandu grass and the Stylosanthes Campo Grande consortium do not influence the total accumulation of forage.

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INFLUENCE OF SEED COLOR OF *STYLOSANTHES CAPITATA VOGEL*. IN THE VIGOUR

Levi Suzigan Krepischi¹, Noêmia Karen de Oliveira², Ariadne Morbeck Santos Oliveira³, Diego Sousa Pereira⁴, João Almir Oliveira⁵.

Keywords: vigour, forage, seed coat color, *Stylosanthes capitata* Vogel.

Introduction: The *Stylosanthes capitata* Vogel is forage with high potential of use, due to its adaptation to and consequently there is a greater demand in the market for high quality seeds. This forage shows heteromorphism in the seeds and in this context, the objective was to evaluate the relationship between seed coat color and seed physiological quality in *Stylosanthes capitata* Vogel.

Material and methods: The experiment was carried out at the Central Seed Laboratory in the Department of Agriculture, Federal University of Lavras (UFLA), Brazil. Three seedlots of *Stylosanthes capitata* Vogel were used, which were homogenized and the seeds were visually separated by yellow, brown, black and also a sample without separation. After the division, 12 treatments were obtained, in which the physiological quality was evaluated (germination test, first germination and electrical conductivity count). The experiment was conducted in a completely randomized design, in a 3 x 4 factorial design, three seedlots and four color groups (black, yellow, brown and without separation). Data were submitted to analysis of variance and means clustering using the Scott-Knott test at 5% significance.

Results and Discussion: Lot 1 obtained the best results in all the tests of determination of the physiological quality. Black seeds presented lower values than the others for all analyzed parameters. The seeds of lot 1 presented higher average percentages of normal seedlings than lots 2 and 3 for all the color groups. The percentage of black seed germination was lower than that of yellow, brown and mixed seeds in all lots. The yellow seeds had higher mean values than the other colors in lots 2 and 3. Percentage of viable seeds according to tetrazolium test in *S. capitata* seeds of different seedlots and colors, the seedlot 1 presented the highest percentage of viable seeds for all color groups. The viability of the seeds in lot 2 was lower than in the other lots for all colors except brown and black, which were statistically similar to those in lot 3. Yellow seeds presented higher means compared to the others in lots 2 and 3. The lowest viability results were found for the black color group, which presented lower means than yellow, brown, and mixed seeds in all seedlots.
Conclusions: It was concluded that there is a relationship between seed color and physiological and physical quality of Stylosanthes seeds.

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Abstracts

OVERCOMING DORMANCY OF PERENNIAL SOYBEAN SEEDS

Juliana Maria Espíndola Lima¹, Elizabeth Rosemeire Marques², Maria Laene Moreira de Carvalho³

Keywords: germination, Neonotonia wightii, physiological quality

Introduction: Neonotonia wightii is a legume originated from Africa, widely used in intercropping pastures. It was introduced in Brazil in the 50’s and it presents high forage value for pastures. The use of tropical legumes with the purpose of increasing quality and quantity of the pastures requires the knowledge about the species and cultivars to be used. In some legumes plants, there is the production of dormant seeds because of their teguments impermeable to water, which prevents the process of germination. Today there are many methods to overcome physical dormancy in seeds and finding the best method is important to have a uniform stand of seedlings in the field. The objective of this study was to evaluate methods of overcoming dormancy in perennial soybean seeds.

Material and methods: The design was completely randomized with four repetitions of fifty seeds. The treatments used to overcome dormancy were: control, sulfuric acid (10, 15 and 20 minutes), water at 100 °C (10, 20 and 30 seconds), dry heat at 65 °C (4, 6 and 8 hours), humid heat at 65 °C (4, 6 and 8 hours) and sandpaper (1, 2 and 3 minutes). It was made germination (normal seedlings, hard and dead seeds), speed of embedded seeds, speed of seed protrusion and speed of germination (normal seedlings) to evaluate all treatments.

Results and Discussion: It was observed frailty of the tegument after overcoming dormancy of the perennial soybean in all treatments, causing a general average of 52% of dead seeds. The treatments that had the lowest number of dead seeds were those which did not use water in the process. However, only treatments with sulfuric acid showed a higher percentage of germination above 40%. Thus, for perennial soybean seed is important to use a method to sufficiently remove the mucilage around the tegument without making the seed absorb water too fast, which could kill it in the process, or after.

Conclusion: The best treatment tested to overcome dormancy in perennial soybean seeds is sulfuric acid (10, 15 and 20 minutes). More need to be studied about the tegument structure, in other to increase the percentage of seed germination that is still very low even after overcoming dormancy.

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PHOSPHORUS FERTILIZATION IN THE FOURTH REGROWTH OF SUGARCANE AND FORAGE PRODUCTION

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Keywords: agricultural management, chemical composition, dairy farming, mineral nutrition

Introduction: Sugar cane is widely used as forage for animal feed, but it has nutritional limitations due to low levels of protein, phosphorus and sulfur. However, phosphorus fertilization can improve the nutritional quality of sugarcane, as it influences the uptake and metabolism of nitrogen and carbon as well as protein synthesis by the plant. In sugar cane cultivation, phosphorus is typically applied at the bottom of the planting furrow, and this is often not enough to ensure adequate P supply for regrowth, especially after the third or fourth cutting of the sugarcane. Thus, there may be a regrowth response to phosphorus fertilization. However, attention should be paid to soil acidity, especially with regard to exchangeable aluminum, as it reacts with phosphorus and the resulting aluminum phosphate is of low solubility. Thus, a small amount of phosphorus will reach the sugar cane root system and will influence plant metabolism, growth and yield. For this reason, one must correct the acidity in soils with exchangeable aluminum prior to applying phosphorus fertilizer in the regrowth period. No results were found in the literature of studies on phosphorus application in the regrowth of sugar cane intended for animal feed. Thus, the aim of this study was to evaluate forage production of sugarcane variety RB92579 in response to phosphorus fertilization applied in the fourth regrowth of sugar cane in soil without exchangeable aluminum.

Material and methods: The soil of the study is of sandy texture and presented the following chemical characteristics at 0-20 cm: pH in H₂O = 5.9; P (extracted with Mehlich) = 15 mg dm⁻³ and base saturation of 45%. The study was conducted in a randomized complete block design with four replicates. The doses of phosphorus were 0 (control); 30; 45; 60 and 90 kg of P per hectare,
applied at the bottom of the planting furrows between the rows of sugar cane. The source of phosphorus was triple super phosphate. All the plots were fertilized with nitrogen and potassium at doses of 100 and 120 kg per hectare, respectively. The plots consisted of six furrows of five meters in length, spaced 1 meter apart. At the end of October 2017, sugarcane was harvested and the four central furrows of each plot were sampled. We evaluated forage production and crude protein, phosphorus and sulfur concentration in dry matter, as well as sucrose content in the stalks. The results were submitted to analysis of variance.

**Results and Discussion:** Phosphorus fertilization did not influence any of the variables evaluated in this study. The average forage yield was 90 t natural matter per hectare. The average contents of crude protein, phosphorus and sulfur were 18.75; 0.8 and 0.7 g per kg of dry matter, respectively. The sucrose content in the stalks was 15%, which indicates that the sugarcane was ripe.

In Alagoas, the main growth phase of sugar cane is from May to August, which is the period of greatest rainfall. In 2017, rainfall during this period was well distributed, totaling 1,313 mm. This volume of rainfall may have contributed to the lack of response of the sugar cane to phosphorus fertilization, because studies have shown that the critical level of phosphorus in the soil decreases with increasing available water content. The study is ongoing and new evaluations will be carried out in the fifth regrowth of sugarcane.

**Conclusion:** Phosphorus fertilization applied between the rows of the fourth regrowth of sugarcane did not affect on any of the variables evaluated in this study. The good distribution of rainfall in the growth phase of sugarcane may have contributed to this result.
PHYSIOLOGICAL QUALITY OF COATED AND STORED BRACHIIARIA SEEDS

Thaísa Fernanda Oliveira¹, Diego de Souza Pereira¹, Janaína Guarieiro Ribeiro de Assis¹, Márcio do Carmo¹, Maria Laene Moreira de Carvalho¹ and Renato Mendes Guimarães¹.

Keywords: germination, tetrazolium, conventional room, cold room.

Introduction: Seed quality is importance to ensure the hight production, and storage allows maintenance of vigor until sowing, however little is known about the effect of storage conditions of coated seeds. This work aimed to evaluate the effect of the storage on the physiological quality of coated seeds of Brachiaria hibrida cv. Mulato II.

Material and methods: Four lots of scarificated seeds were used and treated with CRUISER® 350 FS insecticide at the dose of 250 mL/100Kg and coated. After that the seeds treatment and coating were stored in two environments; conventional (room temperature of 25-30°C) and refrigerated (cold room 10°C). The physiological seed quality was evaluated by the germination and tetrazolium tests in seven storage periods, corresponding to the 0, 90, 180, 270, 360, 450 and 540 days. A completely randomized design was used, with three replicates of 100 seeds, in a 4x7x2 factorial with factors (four seed lots, seven storage periods and two storage environments).

Results and Discussion: The 3 and 4 lots showed no difference in the percentage of normal seedlings over the storage periods, with averages of 71 and 75%. While the 1 and 2 lots had a decreasing linear behavior, with values of 67 and 64% in the storage time of 0 days decreasing to 40 and 43% to the 540 days of storage. Regarding the types of environment, these differed only in the period of 270 and 540 days of storage, in which the seeds germination in conventional storage showed low results to the cold room. Seeds stored in a refrigerated environment at 10 °C had no change in the percentage of normal seedlings, with an average of 68%. The conventional environment reduced the percentage of normal seedlings from 72% (0 days) to 45% at 540 days. The 3 lot showed higher seed viability in relation to the others and there was also no variation over the storage periods, with an average of 85% of viable seeds.

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Differences between the germination values and the tetrazolium viability test were observed due to dormancy present in the seeds even after the scarification process and chemical treatment of the seeds, this was more evident in the 1 and 2 lots. The seed dormancy in the species of *Brachiaria* is caused by different factors, which can occur alone or in combination. According to the results of the tetrazolium viability test, it was observed that, regardless of the storage period, there were significant differences among the lots evaluated for seed viability.

**Conclusions:** The conventional storage environment improve the physiological dormancy overcoming and accelerates the loss of viability for hybrid *Brachiaria* cv. mulatto II. Cold room storage preserves seed dormancy and maintains physiological quality of normal seedlings during the storage period.
Abstracts

**POPULATION DYNAMICS OF TANZANIA GRASS TILLERS SUBMITTED TO NITROGEN DOSES IN THE AMAZON**

Fernando Oliveira Pinheiro Júnior¹, Amanda Machado de Lima², Tamyres Braun da Silva Gomes³, Antônio Barbosa Smith Júnior⁴, Nauara Moura Lage Filho⁵, Ebson Pereira Cândido⁶

**Keywords:** nitrogen fertilization, *Panicum maximum*, seasonality, tillers.

**Introduction:** The low productivity of pasture areas in Brazil is one of the main causes of the low profitability and competitiveness of animal production systems in relation to other agricultural systems, therefore the need to understand the growth dynamics of forage plants, to obtain a management more correct. The objective of this study was to evaluate the effect of different nitrogen doses in relation to the demographic pattern of tillers and population density of tiller of *Panicum maximum* cv. Tanzania and the structure of the forage canopy.

**Material and methods:** The work was carried out at the Federal Rural University of Amazonia, in the municipality of Igarapé-Açu-PA, from August 2016 to August 2017. The experimental units were distributed in a randomized complete block design with six treatments and five blocks. Each treatment consisted of five replicates, totaling thirty experimental units arranged in bed form, each measuring 12 m² (3m x 4m) separated by corridors of 1m wide. Nitrogen fertilization was performed in the rainy season once a month, with a 30 day interval, with the following treatments: nitrogen fertilization, with 100 kg/ha⁻¹, 200 kg/ha⁻¹, 300 kg/ha⁻¹, 400 kg/ha⁻¹, and 500 kg/ha⁻¹ of N, respectively, and were then divided into 6 urea (nitrogen fertilizer) applications and applied in January, February, March, April, May and June. While the potassium fertilization (KCl) used was 20g in each treatment. The variables analyzed were tiller appearance rate, tiller mortality rate, tiller survival rate, and pasture stability index. The means of the treatments were estimated using the LSMEANS program and, in the presence of significant interaction, the comparison of the means of each treatment between the different climatic seasons was performed by the F-test of 5% probability, using the SLICE program command.

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Results and Discussion: The treatments of the variable rate of appearance of tillers compared to each other (TApPe) showed no differences (p > 0.05) differently from periods, where there was an increase in tiller population in the period very rainy (1.20 [number of tillers] 100 tillers - 1.30 days⁻¹) when compared to the less rainy period (0.75 [number of tillers] 100 tillers⁻¹, 30 days⁻¹). The tiller mortality rate (TMPe) of Tanzania grass, as well as the TApPe, presented the greatest response in the very rainy period where water availability is abundant, with rates of 0.54 and 0.91 [number of tillers] .100 tillers⁻¹. 30 days⁻¹ for the periods rainy and very rainy, respectively, being that all treatments were statistically the same, not differing between them. In the dry season, where there was a lower rate of apparition, as well as the lower mortality rate resulted in higher tillers survival rate (TSPe), in which the averages were significant only between periods (2.74 and 2.40 [number of tillers] .100 tillers⁻¹, 30 days⁻¹) for the rainy and very rainy periods respectively, presenting equal results between the nitrogen doses. The stability index had no significant difference (P < 0.05) between treatments, however, differences were observed between periods (p > 0.05) with values of 274.78 e 244.84 for the periods rainy and very rainy, respectively.

Conclusions: The nitrogen fertilization did not influence the population dynamics of the tillers, however, there is a great influence of the seasonality in the same variables, being that during the rainy season there was more renovation of the pasture. It was observed that during the period with less water availability pasture tends to remain without decreasing the tiller population.
CONSERVATION OF BRAQUIÁRIA SEEDS TREATED WITH INSECTICIDE

Silvana Fraga da Silva¹, Ana Maria Oliveira Ferreira ², Diego de Sousa Pereira³, Adriane Duarte Coelho⁴, Márcio Antônio Pereira do Carmo⁵, Maria Laene Moreira de Carvalho⁶

Keywords: chemical treatment, germination, Urochloa híbrida cv. Mulato II, viability.

Introduction: The seed treatment using insecticide gives to the plant conditions of self-defense, allowing greater potential for initial development of the crop. However, knowledge regarding the action of chemical control during storage should be known, since these products, to be used, should not negatively interfere in the physiological quality of seed lots. Thus, the present work had the objective of evaluating the effect of seed treatment using insecticide on the conservation of hybrid Brachiaria cv. Mulato II.

Material and methods: Seeds of Hybrid braquiária cv. Mulato II were submitted to an insecticide treatment called CRUISER® 350 FS at the dose of 250 mL / 100 kg, then packed in paper bags, and stored in a conventional environment (20-30 °C) and cold chamber (10 °C) for 18 months. Every 90 days the following tests were performed: 1) germination: percentage of normal seedlings at 21 days, and 2) tetrazolium: evaluated according to the viability of the seeds. The experimental design was a completely randomized, in a 7x4x2 factorial design, which was seven storage periods (0, 90, 180, 270, 360, 450 e 540), four lots, and two environments (conventional and cold chamber). The data was submitted to analysis of variance and the means compared by Tukey test at 5% probability, for qualitative data, and polynomial regression analysis, for quantitative data.

Results and Discussion: In the evaluation of the seed lot profile, there was superiority in the germination of lots 3 and 4 in relation to the others, after 270 days of storage. This superior effect of lots 3 and 4 was also observed in the seed viability by the tetrazolium test. The refrigerated environment allowed superior conservation of seed germination. However, in the conventional environment, all the lots had lower germination, due to the high temperature and relative humidity conditions, which provided higher deterioration, with consequent action on

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the seed metabolism. During storage, all lots had a reduction in physiological quality at constant rates, having lots 1 and 2 the highest physiological losses (38 and 42%). On the other hand, lots 3 and 4 had increases in germination until 360 days, and also greater viability throughout the storage period. The influence of the storage environment was also observed in seed germination and viability. In the cold chamber, germination remained constant from 0 to 540 days of storage, whereas in conventional environment germination was positive increasing up to 180 days, since it provided conditions to break the physiological dormancy, an effect not observed on seeds in refrigerated environment, which preserves the physiological quality of the seeds, however, it does not favor the overcoming of dormancy.

**Conclusion:** Treated seeds of *Hybrid braquiária* cv. Mulato II have preserved physiological quality when stored in cold chamber environment.
CHEMICAL CHARACTERIZATION OF UROCHLOA DECUMBENS IN THE RECÔNCAVO OF BAHIA CONSIDERING THE TIMES OF THE YEAR

Laiza Santos Peixoto¹, Hackson Santos da Silva², Tiago Lima da Silva³, Adriana Regina Bagaldo⁴, Daniele Rebouças Santana Loures⁵, Fabiane de Lima Silva⁶

Keywords: forage, bromatology, pasture

Introduction: The choice of forage grass to form a pasture should be careful, considering the relationship with seasonal equilibrium and acceptability of the animals, and its production and quality are one of the main factors capable of affecting the viability of the grazing system. The Brachiaria genus is responsible for about 80% of the entire pasture area cultivated in Brazil (Hodgson and Silva, 2002). Having a good tolerance to low fertility soils, fast establishment, high competition with invasive plants, and good efficiency in soil protection against erosion, contributes to the acquisition and rapid dissemination of these species. Thus, the present work had the objective of qualitatively characterizing a pasture of U. decumbens in two evaluation periods, rainy and dry, in the region of the Recôncavo of Bahia.

Material and methods: The study was conducted at the Federal University of Recôncavo of Bahia, Cruz das Almas campus, from June 2016 to January 2017. Laboratory analyzes were performed at the Food Analysis Laboratory of the same institution. It was used an exclusive pasture of U. decumbens established in 2014, with an area of 0.5 hectares, sampling was performed in the water (June) and dry (January) periods. Samples were collected using the methodology of 0.5x0.5 m square random cast, with 10 replicates. After collection, the samples were taken to the laboratory to obtain the green weight, then placed in an oven (60 ± 5°C) until they obtained constant weight for 72 hours, and then the dry weight was obtained. The dry samples were crushed and stored for evaluation of dry matter (DM), crude protein (CP), ethereal extract (EE), neutral detergent fiber (NDF) and acid detergent fiber (ADF) following the methodologies described by SILVA & QUEIROZ (2002) and lignin (LIG). The data were submitted to analysis of variance, comparing the means by the Tukey test at 5%, using statistical software R.

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Results and Discussion: For DM, there was a lower content in the rainy season and an increase of 26.20% for the dry season (value < 0.05). Such an increase in its content can be justified by the higher solar incidence possibly linked to the maturity of the plant. For the variable NDF and ADF, in the rainy season the *U. decumbens* presented a better average in relation to winter (value < 0.05), being 56.49% and 25.28% respectively. As recommended by the literature, NDF levels above 60% may interfere with forage consumption by the animal. The values of lignin found in forage analyzes presented higher value in the dry period (value < 0.05), being directly related to the higher DM content and fibers, besides the age of the plant and the climatic factor collaborating for the difference found. The CP content found for both the rainy season (6.32%) and dry (4.52%) were below 7%, not meeting the nutritional requirements for ruminants, as suggested in the literature. Similar results were found by other authors what when evaluating *Brachiaria hybrid species* cv. Mulato II and *Brachiaria brizantha* cv. Piatã found a significant decrease in the mean CP content as a consequence of maturation and/or decrease in rainfall indices.

Conclusions: During the period evaluated, the dry season linked to the maturity of the plant influenced the bromatological characteristics of the species evaluated actively, however, the *U. decumbens* pasture presented a reasonable potential in its nutritional value in the period in which it was higher the rainfall index for the region.
SODIUM MONENS IN ASSOCIATED TO DIFFERENT MAIZE PROCESSING IN EWE LAMBS PERFORMANCE

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Keywords: feedlot, ionophores, rehydrated corn grain silage, sheep.

Introduction: Corn is the main energetic ingredient used in diets of several animals, making it primordial the search for forms of storage and processing that optimize the use of this grain. One form of processing is the rehydration of the ground corn grain with its subsequent ensilage, which favors its fermentation and the degradation of the protein matrix that recovers the starch granules exposing them, favoring their digestion and absorption. In the search to maximize the efficiency of the use of this food modality, the inclusion of ionophores can contribute to reach this objective through changes in the microbial population of the rumen and, consequently, in the pattern of fermentation of foods. The objective of this study was to evaluate the performance of feedlot lambs under conditions of use of ionophore (sodium monensin) in diets containing ground corn grain, whether or not submitted to the rehydration and ensiling process.

Material and methods: Sixteen crossbred ewes (mean weight and initial age of 26.50 kg and 135 days, respectively) were randomly distributed among four treatments in a 2x2 factorial experimental scheme, which relate to the processing form of inclusion of corn grain in the concentrate composition and whether or not to include monensin sodium in the concentrates (30 ppm dose). The treatments were: dry ground corn grain, without monensin sodium (DG-M); dry ground corn grain, with monensin sodium (DG+M); rehydrated corn grain silage without sodium monensin (RG-M) and rehydrated corn grain silage with sodium monensin (RG+M). For the preparation of rehydrated ground corn silage, 35 kg of water was added per 100 kg of milled dry corn. The whole mixture was homogenized until the proportions were reached, then the amount was packed in steel drums (200 liters), which was lined internally with a black plastic bag. The material was sealed and the fermentation period was 30 days. The parameters studied were daily dry matter intake (DMI) - expressed as total values (g/animal/day) and in terms of metabolic live weight (g/kgLW⁰.⁷⁵) - average daily gain (ADG), expressed as total values (g/animal/day) and feed efficiency.

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Results and Discussion: There was no significant interaction between the factors considered in the work (corn processing x inclusion of sodium monensin), therefore, the results were analyzed separately. The corn processing in the diets did not interfere (P > 0.05) in the DMI results, obtaining values of 1,035.72 and 969.13 g/animal/day for the RG and DG, respectively, implying in intakes of 91.69 and 78.60 g/kgLW$^{0.75}$. The inclusion of sodium monensin allowed DMI of the order of 972.28 and 1,032.56 g/animal/day for the treatments “+ M” and “-M”, respectively (82.31 and 87.99 g/kgLW$^{0.75}$). Regarding ADG, no effect (P > 0.05) of the factors was identified. Processing forms resulted in ADG of 201.90 and 187.40 g/animal/day for RG and DG treatments, respectively. The inclusion or not of sodium monensin allowed ADG of 200.40 and 188.90 g/animal/day for the treatments “-M” and “+ M”, respectively. The overall food efficiency observed in the study was 0.19. Although no significant differences were identified between the treatments, the values obtained are numerically manifested in agreement with the information in the literature, according to which, the DMI is higher when adopting diets with rehydrated corn silage. Regarding the use of sodium monensin, the adoption of inclusion results in reduction of DMI.

Conclusions: It can not be said that there is an advantage in the processing of dry corn (rehydrated and ensiled or simply ground), nor in the inclusion of sodium monensin on the performance of ewe lambs in feedlot systems, at least in the context of the dosages and forms worked in this research. These aspects deserve further research efforts.