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A review

Ammoniation on the quality of tropical grasses: a review

Amonização sobre a qualidade de gramíneas tropicais: uma revisão

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Abstract: Elevation of forage nutritional value is possible through treatments that can be biological, physical and chemical. The chemical treatment of roughage with low nutritive value allows to improve the digestibility of cellulose and hemicellulose, due to the expansion of the cellulose molecules. The positive results of the ammonization process are evidenced by the increase of the crude protein content and reduction of the fibrous compounds of the treated material.

Key words: ammonia, digestibility, neutral detergent fiber

Resumo: A elevação do valor nutritivo da forragem é possível através de tratamentos que podem ser biológicos, físicos e químicos. O tratamento químico de volumosos de baixo valor nutritivo permite melhorar a digestibilidade da celulose e da hemicelulose, em razão da expansão das moléculas de celulose. Os resultados positivos do processo de amonização são comprovados pela elevação do teor de proteina bruta e redução dos compostos fibrosos do material tratado.

Palavras-chave: amônia, digestibilidade, fibra em detergente neutro

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Introducion

One of the main challenges of feeding of ruminants is the reduction of costs in production, from alternatives which can be adapted to each situation. The forage production in the Northeast

region of Brazil is dependent on the distribution of rainfall during the year, which reflects directly on the nutritional quality of the bulky, and that consequently cause economic losses in animal production during the period of shortage (GARCEZ et al., 2014).

The nutritive value of the forage varies with a number of factors, among which are the age of the plant, soil and fertilization carried out genetic differences between species and varieties, seasons of the year and sequence of cuts (GOMIDE et al., 1976). The elevation of the nutritive value of the forage is possible through treatments that may be biological, physical and chemical properties, and has as its main purpose to make it more digestible through changes in their cell wall, allowing then the action more pronounced microbial enzymes in the rumen (REIS et al., 2014).

Rosa & Fadel (2001), In a review addressed that, although all of these processes are technically possible, many are not economically viable in Brazilian conditions, according to the same authors, among the chemical treatments evaluated, especially with dry grasses or crop residues and, more recently, with hay, highlighting the use of anhydrous ammonia (NH_3) or the urea, a process called ammoniation.

According to Gesualdi et al. (2009), the use of urea and other compounds (ammonia) aims to improve the nutritional value, reflecting an increase in the crude protein and digestibility of dry matter, thereby raising the consumption and consequently the performance of animals, as well as providing improvements in the conservation of forage. The process of ammoniation exerts beneficial effects on the fiber fraction of grasses, acting in the solubilization of hemicellulose and lignin, resulting in a decrease in the contents of neutral detergent fiber (PEREIRA et al., 1990). The treatments of fodder rich in lignin and neutral detergent fiber, with anhydrous ammonia, began in the first decade of the twentieth century, around the 1970s, the works were quite explicit in Europe (ROSA et al., 2001). In Brazil, the research work started in 1984, at the Department of Animal Science of Universidade Federal de Viçosa, (GARCIA, 1992).

Treatment with ammonia and its effects

Ammonia is the name given to the compound that has in its composition a nitrogen atom and three hydrogen atoms (NH_3). The anhydrous ammonia has a N high (82%) and can be found in the liquid under low temperatures or pressures under relatively high (GARCIA and PIRES, 1998).

The urea behaves as a crystalline solid technically produced from ammonia

and carbon dioxide (CO2). It dissolves easily in water, is widely used as fertilizer or supplied to ruminant animals as a source of nitrog non-protein (NNP), has a low cost and easy manipulation (GARCIA and NEIVA, 1994; CÂNDIDO et al., 1999).

Since ammonia settles also known as sodium hydroxide ammonia (NH3OH) or water-ammonia, presents application similar to anhydrous ammonia, the main difference is in the large volume of liquid used compared to the small amount of anhydrous ammonia, because sodium hydroxide has a content of N less (29%).

Garcia and Neiva, (1994), reported that the action of ammonia inside of the material promotes an unstructured, i.e., a disruption in the complex formed by the components of the fiber (cellulose, hemicellulose and lignin), presenting a better exposure of the contents to micro-organisms and, consequently, increasing the degree of utilization of different fractions of fiber by the same.

According to Goto and Yokoe (1996), two theories may explain how the ammonia acts on the part of the fibrous straw mulch. The first, called reaction of amonólise mentions the ability of ammonia in to form a complex with the pulp, producing an amide, by which the reduction in crystallinity of cellulose, through the breakdown of hydrogen bridges, increasing his weakness and providing a better enzymatic digestion.

Still according to the same authors, the second theory refers to ammonia by acting as a alkali through a reaction of alkaline hydrolysis, whereby the ammonium hydroxide (NH_4OH) resulting from the reaction of ammonia with the moisture present in the straw mulch, reacts with the esters derived from connections between the structural carbohydrates promoting small disruptions in these interpolímeros. In Table 1, presents the results of some studies that evaluated the effects of ammoniation of hay of tropical grasses of low quality, with urea or anhydrous ammonia. All jobs showed improvements in the nutritional value of hay, which, in general, have reductions in fibrous fractions and increasing levels of crude protein and digestibility of dry matter. The effects on the nutritional value of forages by the use of urea or ammonia tend to be similar, but differences can occur due to differences in the levels of urea used in the treatment time and by inherent features of the bulky.

As can be observed for Brachiaria Decumbens, there are differences in the chemical composition of the hay not treated, which influence the magnitude of the responses of the ammoniation.

Table 1. Effect of treatment with urea or ammonia in hays tropical grasses of low nutritional quality.

Tropical grasses	Treatments	% of Dry Matter						
		CP	NDF	ADF	Cel	Hem	Lignin	IVDM
***Brachiaria Decumbens*[1]**	Urea 0.0 %	3.9 b	82.2 a	50.0 b	39.6 a	32.0 a	7.4 b	40.9 b
	Urea 5.0 %	14.0 a	82.8 a	52.0 a	39.3 a	30.4 b	9.5 a	45.5 a
***Brachiaria Decumbens*[2]**	Urea 0.0 %	2.8 c	83.9 a	51.7 a	42.4 a	32.2 a	9.3 a	47.5 c
	Ammonia 3.0 %	9.7 b	79.4 b	48.1 b	40.2 b	31.3 a	8.0a b	59.6 a
	Urea 5.0 %	12.0 a	82.0 a	52.7 a	45.5 a	29.2 b	7.2 b	54.2 b
***Brachiaria Decumbens*[3]**	Urea 0.0 %	5.4 b	87.7 a	49.7 a	38.4 a	38.0 a	10.2 a	54.0 b
	Urea 6.0 %	18.7 a	80.5 b	45.6 b	35.5 b	35.0 b	8.8 b	66.7 a
***Brachiaria Decumbens*[4]**	Urea 0.0 %	4.4 a	82.8 a	46.2 a	38.8 a	36.3 a	7.8 a	48.7 c
	Ammonia 3.0 %	12.2 b	78.2 b	46.6 a	38.5 a	31.6 b	8.1 a	63.5 a
	Urea 5.4 %	12.9b	77.5 b	45.2 a	38.6 a	32.3 b	7.7 a	59.8 b
***Brachiaria Brizantha*[4]**	Urea 0.0 %	2.6 c	81.4 a	50.5 a	43.0 a	30.8 a	7.9 a	41.2 c
	Ammonia 3.0 %	12.2 b	72.1 b	49.5 a	43.3 a	22.6 b	7.6 a	61.6 a
	Urea 5.4 %	14.4 a	77.0 b	46.5 b	40.3 b	26.7 b	7.7 a	55.8 b
***Hyparrhenia Rufa*[4]**	Urea 0.0 %	5.5 b	80.4 a	58.6 a	40.8 b	26.8 a	8.9 a	46.8 b
	Ammonia 3.0 %	13.6 a	76.2 b	54.7 b	42.9 a	21.5 b	9.1 a	58.4 a
	Urea 5.4 %	14.1 a	77.8 b	54.0 b	41.1 b	23.8 b	8.9 a	56.4 a

CP: Crude protein; NDF: neutral detergent fiber; ADF: Acid detergent fiber; Cel: Cellulose; Hem: Hemicellulose; IVDM: In vitro digestibility of dry matter. Source: Adapted from: [1]Schmidt et al.(2003); [2] Fernandes et al. (2002); [3] Gobbi et al. (2005); [4] Reis et al.(2001).

In fact, Alfaya et al.(2002), studying the effect of ammoniation with urea on the quality parameters of the hay of the Grass-annoni (*Eragrostis plana Nees*), observed that the alkalinizing effect of treatment of Grass-nnoni 2 determined changes also in the parameters of the fiber fraction, the analysis of variation in the levels of NDF showed significant effect for factor treatment of hay.

Factors that affect the process of ammoniation

According to Sundstol and Coxworth (1984) several factors can affect the efficiency of the ammoniation and final product, especially if the amount applied, the period of treatment and the moisture of hay. In addition to these, the buffer capacity of plants has pronounced effect on efficiency of treatment (DIAS DA SILVA

and GUEDES, 1990). In treatments in which uses urea as a source of ammonia, moisture and the activity ureática have outstanding influence in the responses of the bulky amonizads (SUNDSTOL and COXWORTH, 1984).

Applied dose

According to Pires (2000), the dose of nitrogen was one of the first factors to be evaluated in studies on ammoniation of bulky. Doses above 4% of anhydrous ammonia and 7.5% of urea in DM are not normally used, because there are improvements in the quality of the material treated. Dolberg (1992) reported that the greater efficiency of treatments with the use of urea can be obtained when the roughage has moisture content of 30%, and the urea is applied at a dosage of 4 to 8% of the DM of the forage treated.

Roth (2008), using different doses of urea (3 or 5% in DM) and anhydrous ammonia (3% in DM), in hay residue level of post-harvest of seeds of Brachiaria brizantha cv. Palisade containing different moisture contents (15, 25, or 30%), however, the hay not treated showed a lower crude protein content of 3.32% in relation to the treaties, regardless of moisture content, but this difference was being that the work in literature show results more pronounced on voluminous of worse quality.

Work with ammoniation of bulky of low quality recommend 3 to 4% of anhydrous anomia based on DM, (GARCIA and NEIVA, 1994).

Padua et al., (2011), evaluating the effect of the dose of urea and period of treatment on the composition of the hay of Paspalum Notatum, which the treatments were: the following doses: 0 (control); 0.5; 1.0; 1.5; 2.0 and 2.5% of inclusion, and however observed that the levels of NDF and ADF decreased linearly as a function of doses of urea applied to the material treated, the same authors attribute this fact in respect, ammonia product of decomposition of urea can act on the molecules of hemicellulose, promoting the breakup of links and the partial solubilization of this component, as already mentioned in this review.

not significant in the hay treated with 3% urea. The other treatments, with 5% of urea and 3% of ammonia, regardless of moisture content increased from 7.43 to 13.9 percentage points on the content of CP when compared to control group, having featured in the treatment with 5% urea with 30%. The responses of treatment with ammoniation can vary according to the quality of the material to be treated,

Carvalho et al., (2007), studying the degradabilidad in situ da dry matter and fiber fraction from sugar cane bagasse

treated with urea, in which it was used four levels of urea - 0%, 2.5%, 5.0% and 7.5%, for the treatment of sugar-cane bagasse with 40% of DM, which even the greatest level of NH3 applied to straw mulch by the authors was able to promote a ruminal above 60%, as observed in treatments 5% and 7.5% of addition of urea in the present study. These variations may be related to the period of ammoniation, with temperature and the quality of the material quantity applied, because they carry a direct influence on the material treated.

Rocha, et al. (2006) investigated the effect of increasing levels of urea in the ammoniation of elephant grass silage and found that the addition of 4% urea to elephant grass during the silage process has improved its quality, influencing on its chemical composition, increasing the content of crude protein, digestibility in vitro dry matter and reduction in neutral detergent fiber content.

Treatment time

The duration of treatment depends on several factors, which must be taken into consideration, among them is the local temperature and this, in turn, directly influences the rate of hydrolysis of urea, i.e., for each region it is recommended that a length of treatment. Reis and Rodrigues (1991), recommended a minimum period of treatment 15 days in summer and 30 days in times more cold, long enough for the full hidrolise of urea.

In a study performed by Oliveira and Pires (2009), observed effect ($P<0.05$) for interaction doses of urea and period of treatment, presenting greater losses by gases in the period of 60 days, being observed a higher efficiency of urea in the reduction of losses by gases at 30 days of ammoniation on grass.

Tonucci (2006) also using urea and different periods of ammoniation, observed that the higher content of CP was observed with the highest dose of ammonia during the greatest period of treatment which was 90 days, according to the same author also reported in his experiment with grass Tifton-85 amonizado with increasing doses of urea in 3 periods of treatment, that the levels of insoluble protein in neutral detergent and acid detergent insoluble protein showed reductions in response to the presence of ammonia and the period amonizado.

Santana (2010), studying the nutritional value of elephant grass subjected to levels of urea and times and ammoniation, for contents of DM was observed that the values found were from the second week of ammoniation, which did not differ statistically among

themselves. Possibly this occurred by the increase of nitrogen non-protein (NNP) in forrage amonizada.

Moisture content of the grasses

The moisture content of the forage is another important factor that determines the effect of treatment with NH3 and the final results of the material. In tropical conditions, where straws and crop may present humidity levels very low, the moistening of the forage is the most indicated to have better effect of ammoniation (GARCIA and NEIVA, 1994). Fadel et al. (2003), with the aim of assessing the different proportions of water and urea on the chemical composition of rice straw, used the factors 20%, 30% and 40% relate to the amount applied for water and 2%, 4% and 6% to the urea fertilizer (on the basis of dry matter), in accordance with BANZATO and KRONKA (1989). In that found have significant interaction ($P<0.05$) between the proportions of water and urea were added to the medium contents of crude protein (CP) of rice straw. They also noticed that, by data in Table 2, that the medium contents of CP increased ($P<0.05$) with the increasing proportions of urea added. This is normal behavior in the work of ammoniation of bulky low quality, with increases of around 6.00 percentage points on average levels of CP of grass amonizadas.

This is normal behavior in the work of ammoniation of bulky low quality, with increases of around 6.00 percentage points on average levels of CP of fodder amonizadas.

Table 2. Statistical interaction for maximum crude protein (% in DM) of rice straw in different treatments.

Urea (%)	**Water (%)**		
	20	**30**	**40**
2.0	10.20 Ca*	10.93 Ca	10.29 Ca
4.0	15.26 Bb	16.56 Ba	11.46 Bc
6.0	19.82 Aa	18.22 Ab	16.80 Ac

*Medium followed by letters, capital letters in columns and letters in lines, indicate that there was no difference between them by Tukey test ($P>0.05$).

Effects of ammoniation in fibrous compounds

The majority of studies about ammoniation of fodder, by-products of agribusiness and crop has reported that the ammoniation, usually, promotes physical and chemical changes in the concentrations of constituents of the cell wall (GARCIA and PIRES, 1998). The constituents of the cell wall will vary depending on several factors, such as levels to be applied, forage quality, moisture content, period of

treatment and ambient temperature as already mentioned here.

The chemical treatment of bulky, low nutritional value results in increased digestibility of cellulose and hemicellulose, due to the expansion of the molecules of pulp, due to the rupture of the hydrogen bridges and increased hydration of fiber, allowing quick access of microorganisms, which results, consequently, in higher digestibility (BERGER et al., 1994).

Bezerra et al. (2014), when evaluating hay of Buffel grass amonizados with urea, and in relation to the values of NDF, was expected a reduction due to hydrolysis of its components that is intensified when it incorporates ammonia in the material. Still according to the same authors, inefficiency of urea in reducing the levels of fiber fraction in the hay of Buffel grass can be related to the stage of development advanced in the same at time of harvest, which may have reduced the urease activity, reducing the release of ammonia and, consequently, the solubilization of hemicellulose.

Van Soest (1994) reported that part of the lignin and silica is dissolved during the ammoniation and connections of intermolecular ester type between the acid uronic of hemicellulose and cellulose are broken too, with that the cellular content is presented in a better way for microorganisms of the rumen.

In line with the previous authors, Reis et al. (2001) studied the chemical composition and digestibility of hay treated with anhydrous ammonia or urea and observed that the application of anhydrous ammonia or urea has decreased ($P<0.05$) in the levels of NDF and hemicellulose of hay evaluated. Which were registered declines of 6.0 and 4.1 percentage units in the levels of NDF and 5.9 and 3.5 in of hemicellulose, in response to the addition of anhydrous ammonia or urea in the hay.

Morais (2016) studying the effects of ammoniation on the nutritional value of hay of elephant grass harvested after the flowering, observed a linear effect of increasing dose to the fraction of carbohydrates A+B1, and linear decreasing effect for the C fraction, this fraction A+B1 is represented by soluble sugars with rapid degradation by rumen microorganisms, What can increase the efficiency of microbial synthesis and the animal performance, since this fraction A + B1 provides energy more slowly to micro-organisms of the rumen (PEREIRA et al., 2010), while the fraction C indicates the fraction of carbohydrates unavailable in compartments of the digestive ruminants (FAVORETO et al., 2008).

Effect of ammoniation on digestibility, intake and animal performance

The determination of apparent digestibility of fodder amonizadas is considered procedure of great relevance, when it intends to evaluate the efficiency of the ammoniation, because the deterioration and the forage intake are generally correlated and that consequently influence the performance of production (GARCIA and PIRES, 1998).

Cardoso et al., (2004), evaluated the performance of steers Simmental fed sorghum silage, sugar cane and straw of rice treated or not with anhydrous especially with the efficiency of rumination in grams of dry matter, as was observed in the work of Perazzo et al. (2016) in which working with hay of buffel grass amonizado, the intake of food more digestible is of fundamental importance for the animal, having in view, which will address the nutritional requirements more quickly and thus improve the feed conversion.

Okamoto & Miyazaky (1990), using straw of rice, amonizada or not, as the sole source of roughage in the diet of sheep, concluded that the ammoniation has accelerated the reduction in size of the particles during mastication and digestion degradability. These changes have contributed to increase the rate of passage ammonia, and observed a greater ($P<0.05$) daily weight gain for the animals that received mulching amonizada, in relation to the straw mulch more urea and sugar cane, the daily gain of live weight of animals fed with straw mulch amonizada was 27.8% higher than that obtained by animals fed with mulching plus urea. Therefore, the effect of ammoniation, improving the nutritive value of straw treated, particularly their in vitro dry matter digestibility (IVDMD), as well as increasing consumption volunteer.

The digestibility has a positive correlation with the animal behavior, of food, increasing, therefore, the intake of dry matter.

Zanine et al., (2007) observed a linear positive for IVDMD with the addition of the levels of urea. It has been observed even increased the means on digestibility of 53.93%, in the control treatment, to 63.96% at a dose of 3.0%. The improvement of the parameters of digestibility is linked to the increase in the level of protein, reduction in NDF and higher solubilization of hemicellulose (CALIXTO JUNIOR et al. 2007).

Vadivelo & Fadel (2009), evaluated the parameters of digestibility of dry matter of carbonized rice treated with urea and not treated and improvements have taken place in the digestibility of

treated product. The authors justify the result based on the reduction of pulp and the lignin, as well as observed in the study by Balgees et al. (2007). The effect of ammoniation on digestibility of forage crops or some material with forage potential (sugar cane bagasse, rice husk among other waste extremely impregnated), depends on the origin of the product and any other treatment as the addition of uréase on the product. In a study by Gomes et al. (2009), evaluated the effect of treatment with urea on digestibility of carnauba straw, and observed that the treatment without urease, the digestibility was not influenced by the addition of urea in the levels of 2.5, 5, 7.5 and 10%. Already in the treatment with the addition of urease adding 10% provided improvements in digestibility when compared to the other treatments.

Table 3. In vitro dry matter digestibility of carnauba straw treated with levels of urea

Treatments	Lvels of urea (%)				
	0.0	**2.5**	**5.0**	**7.5**	**10.0**
With urease	13.3 b	12.2b	12.9 b	13.7 b	15.7[a]
Without urease	14.7 a	13.1 a	13.5 a	14.3 a	14.9 a

Medium followed by letters equal do not differ by Tukey test at 5% probability. Adapted from Gomes et al. (2009).

It is evident, that depending on the anatomical constitution of the harvester, content of the cell wall, there is a need to use strategies aimed at improving the composition and optimization of the technique.

Final considerations

The ammoniation is a viable alternative because it provides improvements in nutritional value, proven by the elevation of crude protein content and the reduction of the contents of neutral detergent fiber, as well as increasing intake.

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