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Evaluation of the Addition of Urea or Calcium Oxide (CaO) on the Recovery of Dry Matter of the By-Product of Sweet Corn Silage

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Abstract

The objective of this study was to evaluate the effects of the addition of different percentages of urea or calcium oxide (CaO) on the fermentative characteristics and chemical composition of the by-product of sweet corn silage, without whole kernel corn. The experimental design was completely randomized in a 2 × 5 factorial scheme, with two additives (CaO or urea) and five inclusion levels (0, 0.5, 1.0, 1.5, and 2.0% in natural matter of by-product of sweet corn silage). There was interaction between the type of additives and addition levels (CaO or urea) for pH values ($P < 0.05$). The mean pH values ranged from 3.40 to 5.36 in the additive silage. For effluent production, the additive type interaction and addition levels were significant ($P < 0.05$). The addition of CaO independent of the level used was not effective in reducing dry matter (DM) losses during ensilage. The total losses of DM presented a significant increase with the levels of addition of CaO, varying from 91 to 177% in relation to the control silage. The addition of urea to all levels had a satisfactory effect on the total loss of DM, ranging from 38 to 69% improvement in the reduction in relation to the control silage. The additive CaO was not efficient in reducing the fermentation losses and preserving the silage. However, urea was efficient in the recovery of DM in the ensilage process.

Keywords: additive, gases, pH, silage

1. Introduction

Chemical additives such as urea and CaO are available to promote fermentation and preservation or inhibit detrimental processes in a silo. Additives promote the growth of lactic acid bacteria. Silage additives are added during storage (Yunus et al., 2000). More recently bacterial inoculants are used to help natural lactic acid bacteria and lower pH. These additives work best when natural lactic acid bacteria is low as in grass silage. Enzymes are also available to break down forage fiber, and ammonia and acid products are commonly used to improve ensiling. Bolsen et al. (1995) used silage additives to improve fermentation and prevent the production of butyric acid in wet silage. In addition, additives are used to reduce dry matter (DM) losses and to preserve nutrients during or after fermentation (Jaster, 1994). The DM losses can be reduced with the addition of additives, but many of the additives pose a health threat to humans. Therefore, a better understanding of the ensiling process is needed for a producer to wisely decide upon using the additives.

Nowadays nutritionists research additives capable of controlling the population of yeasts, aiming to reduce losses. According to Nussio and Schmidt (2005), the reduction in alcohol accumulation is of great importance for the animal performance due to the losses resulting from the rejection of the feed by the cattle caused by low palatability. If undesirable fermentation is controlled, its use in diets has satisfactory results in animal production (Mendes et al., 2008; Queiroz et al., 2008).

Corn is one of the most important cereals cultivated and consumed in the world, due to the diversity in its use, in feeding human or animal, assuming a relevant socioeconomic role (Fancelli & Dourado Neto, 2000). The fibrous by-products resulting from crop cultivation constitute a major source of nutrients for animal production in developing countries. On small farms, they form the principal feed of ruminant livestock during the dry seasons. Concerns about inadequate utilization of available feeds have led to the establishment of research programmes to improve the nutritive value and utilization of by-product of the crop as ruminant feed. These residues provide fodder at low cost since they are by-products of existing crop production activities Willians et al. (1997). The by-product of the industrialization of sweet corn canned (without whole kernel sweet corn) is composed of straws, ears of corn, which is used *in natura* as roughage for beef and dairy cattle. It is an interesting alternative and could enhance the economic efficiency of the activity (Meneghetti & Domingues, 2008).

According to Vieira et al. (2004), ensiling can result in the losses of nutrients due to the undesirable fermentation processes. Therefore, to overcome the nutritive losses of the ensiled material, certain additives are used. These additives are substances that contribute to the reduction of losses, stimulate fermentation, and enrich nutritional value (Evangelista & Lima, 1999; Vieira et al., 2017). The most commonly chemical additives are urea and CaO, thus this study aimed to determine their effect on the ensiling of sweet corn by-products.

We hypothesize that chemical additives improve quality fermentative and the nutritional value of the silage of by-product sweet corn, thus, it was objectified, with this study, to evaluate the pH, effluents, gases, total loss of DM and recovery of DM.

2. Materials and Methods

2.1 Experimental Site

The experiment was carried out in the cattle sector of the Federal Goiano Institute Campus Morrinhos, located on the highway BR153, KM633 State of Goiás, Brazil. According to Köppen, the climate is type Aw, hot and humid, with an average annual rainfall of 1500 mm, presenting a rainy season in summer and dry in winter.

The corn was planted with the purpose of harvesting whole kernel for industry. The by-products of sweet corn were used to make silage, and two additives calcium oxide (CaO) or urea and five inclusion levels (0, 0.5, 1.0, 1.5, and 2.0% in natural matter).

The by-product were ensiled in plastic buckets (silos) with a capacity of 20 L, equipped with a valve type Bünsen adapted in its lid, to allow to measure the lost of gases from the fermentation.

2.2 Silage Effluent Production

In order to determine the production of effluents, 4 kg of dry sand was placed on the ground of each silo, separated from the residue by a cloth. After the silos were filled, they were sealed with adhesive tape, weighed and stored in a covered area at room temperature for 50 days. After that, the silos were opened, the loss of DM in the silage in the form of gases and effluents was quantified by gravimetry, according to techniques described by Schmidt (2006). The following equation was used to determine the effluent loss.

$$E = [(BWfinal - Tb) - (BWinitial - Tb)]/MF \times 1000 \quad (1)$$

Where,

E: Effluent production (kg/ton of the DM); *BWfinal*: empty bucket weight + sand weight at opening (kg); *Tb*: tare of the bucket; *BWinitial:* empty bucket weight + sand weight at closing (kg); *MF:* matter of forage at closing (kg).

The losses in the form of gases were determined by the difference between the amount of DM of the forage at the silo closing, and the amount in the bucket at the time of the opening. Equation:

$$G = (BWinitial - BWfinal)/(F_{DM}initial \times F_{DM}\%) \times 10.000 \quad (2)$$

Where,

G: Gas losses (%DM); *BWinitial*: Full bucket weight at closing (kg); *BWfinal*: Weight of the bucket filled in the opening (kg); F_{DM} *initial*: DM forage in the closing (kg); $F_{DM}\%$: DM content of forage at closing (%).

The total DM losses were determined by the difference between DM amount of forage silage at the silo closing and the amount of DM in the forage recovered, discounting the loss by effluent and gases. Samples were also collected for the determination of pH and DM. pH and MS were determined according to AOAC (1990).

2.3 Statistical Procedures and Model Evaluation

The experimental design was completely randomized in a 2 × 5 factorial scheme, with two additives calcium oxide (CaO) or urea and five inclusion levels (0, 0.5, 1.0, 1.5, and 2.0% in natural matter), with three replicates. According to the $Yij = \mu + Ti + eij$ model, where, Yij is the value observed in the jth experimental unit that received the ith treatment; μ is the overall mean; Ti is the fixed effect of the ith treatment; and eij is the experimental error related to the experimental unit. Data were analyzed by means of the GLM (generalized linear models) of the SAS/STAT 9.0 software (SAS Institute Inc., 2002), and means were compared using Tukey's test at a 5% significance level. After checking the interaction between the factors and the effect of treatments, the regression analysis was performed at the 5% probability level, as a function of the additive addition levels.

3. Results and Discussion

The mean values of pH, effluent production, gaseous loss, total DM loss, the recovery of DM, and their respective coefficients of variation are given in Table 1. The type of additives (CaO or urea) and the addition levels (0, 0.5, 1.0, 1.5, and 2.0% in the natural matter) showed some relation with the pH values ($P < 0.05$). The variance analysis was significant ($P > 0.05$) between the means of the treatments with CaO or urea. The levels of the additive CaO had a quadratic effect on the variable pH. For urea, the levels showed a cubic response (Figure 1). The mean pH values ranged from 3.40 to 5.36 in the silages with additives, where the silages treated with 1.5% and 2.0% urea in the natural material were the only ones with a pH value in the ideal range (3.8 to 4.2) for a good conservation of the ensiled forage. On the other hand, the control silage showed a pH value below the ideal range, as well as the silage added with 1.0% urea. The other silages showed the values higher than the range established by McDonald et al. (1991). The increase in pH values with the addition of calcium oxide was already expected. Santos et al. (2008) reported that the strongly alkaline nature of the additives offers higher buffer capacity than the untreated silages, implying a higher resistance to pH drop. According to Yunus et al. (2001), urea as a silage additive increases the crude protein content but reduces the fermentation quality of silage by increasing pH and enhancing clostridial bacteria growth, especially in low sugar forages.

Table 1. Mean values of pH, effluents, gases, total loss of DM and recovery of DM

	Silage of by-product sweet corn									CV (%)	Type	Type × Level
	Control	CaO				Urea						
Level (% natural matter)	0.0	0.5	1.0	1.5	2.0	0.5	1.0	1.5	2.0			
pH	3.40	4.78	5.19	5.36	5.25	4.60	3.71	3.83	3.80	4.83	**	**
Effluent[1]	85.28	86.54	88.09	92.40	80.15	77.10	70.74	74.54	77.73	5.46	**	ns
Gases[2]	4.46	7.79	9.95	10.98	13.18	6.32	4.61	3.88	2.77	19.44	**	**
Total lost[3]	8.59	16.49	15.95	15.16	23.87	11.14	5.31	6.67	2.74	25.14	**	**
DM recovery[3]	91.40	83.50	84.04	84.83	76.12	88.85	94.68	93.32	97.25	3.38		

Note. [1] Kg/ton of natural matter; [2] % DM; [3] %; Type: additive effect (CaO or urea); Type × Level: type effect (CaO or urea) vs addition levels (interaction); ** significant at 5% probability; ns: not significant at 5% probability.

During the opening of silos with CaO added silage, a dark brown color was observed for levels 1.0, 1.5 and 2.0%. The same observation was also made by Miranda (2006), while using CaO added silica-treated sugarcane silage; and they reported a different appearance of silage with pH above 4.8, indicating the occurrence of clostridial fermentation (McDonald et al., 1991). The silage treated with 0.5% urea in natural matter showed an increase in pH, which can be explained by the conversion of urea into ammonium hydroxide (NH_4OH) in the presence of moisture inside the silo (Kung, 2003).

In addition to the possible development of undesirable microorganisms (Enterobacteriaceae, *Clostridium* sp. and yeasts) in ensiled forage, the high moisture content also exerts a synergistic effect on pH values. According to McDonald et al. (1981), the clostridial fermentation is undesirable for the forage conservation, because at the cost two moles of lactic acid only one mole of butyric acid is produced, which is a weaker acid and thus causes an increase in pH (Stefanie et al., 2000).

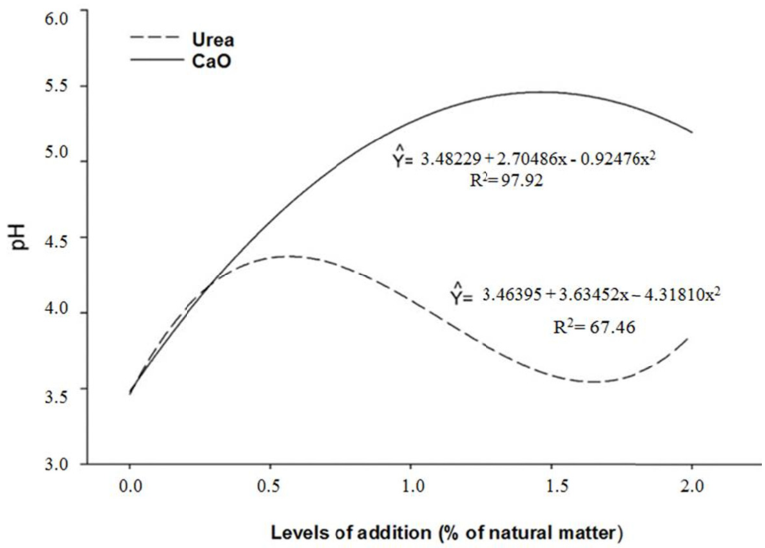

Figure 1. pH values of by-product silages from sweet corn processing as a function of the addition levels of CaO or urea

This effect can be inhibited by higher levels of urea addition (1.0, 1.5 and 2.0% in the natural matter), increasing the development of desirable microorganisms (homofermentative and heterofermentative bacteria). The production of organic acids, mainly lactic acid, influences favorably the pH decrease. At a 2.0% level of urea in the natural matter, a tendency of pH to increase is observed. This increase is possibly related to the higher buffering effect of this level due to the acidification by the organic acids from the ensiling process.

For effluent production, the effect of additive type and its concentration was significant ($P < 0.05$). However, in the decomposition of the variance, the effect of the treatment was not significant ($P > 0.05$) (Table 1). In a study by Schmidt (2010), no effect of the additives on the production of effluents during the ensiling process of peach palm residue was observed. Santos (2007) did not observe any effect of the additives on the production of effluents in sugarcane silage, and attributed this result to the concentration of sugars present in the forage having a hygroscopic action in silage. According to Silva et al. (1994), sweet corn contains 9-14% of sugar, and the levels of the additives in the sweet corn by-products may be influenced by the sugar content.

The additive CaO, independent of the level implied, caused an increase of 1.77% in the effluent production in relation to the control silage. According to Woolford (1978), CaO alters the integrity of the cellular structure, affecting the osmotic pressure and the ability to retain water, which causes cell membrane rupture and extravasation of its contents. On the other hand, the addition of urea resulted in 12.03% reduction in effluent production. It might be possibly due to antifungal action. According to Siqueira et al. (2004), ammonia produced by urea breakdown in silage exerts a toxic effect on fungi and yeasts.

The effluent production observed for the by-products of sweet corn silage was higher when compared to other forages, possibly due to the high moisture and low DM content (21.18%) during ensiling. Oliveira et al.,(2010) reported the effluent yields of 20.4, 69.7, and 37.9 kg/ton of natural material for corn silage, sorghum, and sunflower, respectively. The single most important factor governing effluent production from silage is the moisture content. A high moisture content exerts two main effects on effluent flow. Firstly, the availability of water for seepage is increased, and secondly, the pressure attained within the silage mass is also increased. Thus, a synergistic effect of moisture content and pressure results in a high effluent production (Reynolds & Williams, 1995). The moisture content controls the total quantity of effluent produced over a long period of time and also the rate of effluent production (McGechan, 1990).

The gas production also showed a significant effect of CaO and urea as well as the addition levels ($p < 0.05$) (Table 1). The regression analysis revealed that the levels of CaO and urea have a quadratic response (Figure 2). The additive CaO did not show any effect on the loss in the form of gases, the use of the additive increased from 74 to 195% the gas production in relation to the control silage. This effect can be explained by the pH, as the addition of calcium oxide resulted in a higher resistance to pH drop probably due to the higher growth of the undesired microorganisms. According to McDonald et al. (1991), during the fermentation process, the loss by gas (CO_2)

might be high if fermentation is carried out by *Clostridium* bacteria, which mainly carries out decarboxylation or oxidation processes.

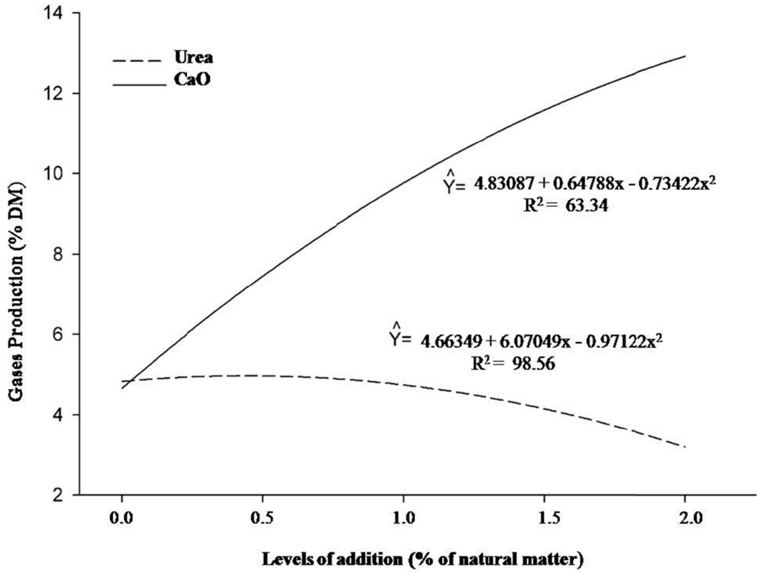

Figure 2. Gases production (% DM) of by-product silages from sweet corn processing as a function of CaO or urea addition levels

The urea added silages showed a reduction of 37.89% in the gas loss in relation to the control silage, except for silage treated with 0.5% urea in the natural matter. This reduction in DM losses by gases is a result of the ammonia action on unwanted microorganisms (Valente et al., 2016). According to Gentil (2007), urea exerts a fungistatic role in ensiled matter, in addition to providing a better fermentation pattern. The level of 0.5% of urea in the natural matter resulted in increased gas losses, possibly as this concentration was insufficient to promote the inhibition of undesirable microorganisms in the ensiled matter.

The variable total loss of DM was significantly affected by the additives, CaO and urea, and addition levels ($p < 0.05$). The regression analysis of the effect of CaO and urea indicated that these additives have a quadratic response (Figure 3).

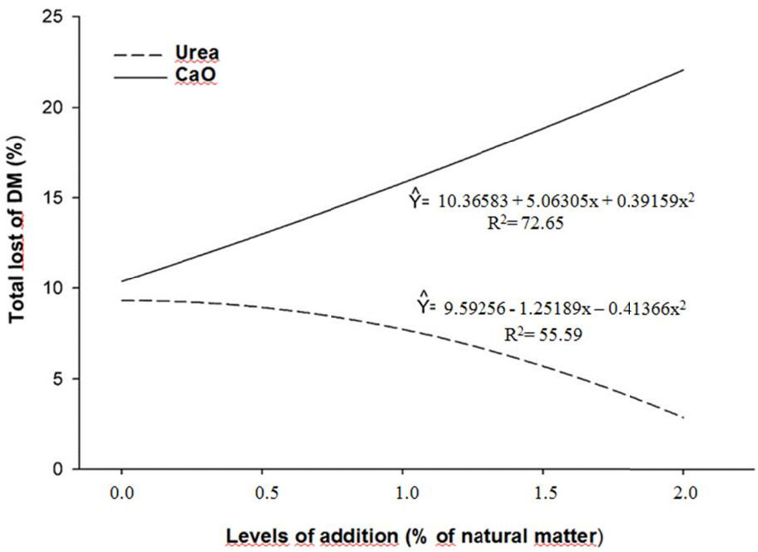

Figure 3. Total DM loss (%) of by-product silages from sweet corn processing as a function of the addition levels of CaO or urea

As reported by Kung Jr. et al. (2003), the use of urea as an additive in silage causes an elevation in pH, and thus inhibit the growth of undesirable microorganisms. According to Schmidt (2006), ammonia released by urea treatment reduces the growth of yeasts and molds, thus reduces ethanol production and, consequently, leads to the lower loss of dry matter and soluble carbohydrates. Regarding calcium oxide, studies of Santos et al. (2008) with sugarcane noted that the addition of both calcium oxide and calcium carbonate promoted the reduction of total and gaseous losses, inhibited alcoholic fermentation and enhanced the recovery of carbohydrates, resulting in silage with the nutritive value similar to that of fresh forage.

The addition of CaO, independent of the level used, was not effective in reducing DM losses during ensiling. As results of DM showed a significant increase with the levels of addition of CaO, varying from 91% to 177% in contrast to the control silage. Although, urea was effective at all levels in reducing the total loss of DM, ranging from 38% to 69% reduction in contrast to control silage. However, silages treated with 0.5 urea in the natural matter showed an increase (29%) in the total loss of DM. These results can be explained by the gas production since it represents the largest fraction of the total loss of DM (57.90% for CaO and 63.86% urea), and the effluent losses did not differ.

The results indicate that the effect of CaO and urea and their concentrations on DM recovery was significant ($p < 0.05$). There was also a treatment effect ($p < 0.05$). Therefore, the differences between the means of treatments with CaO or urea were significant (Table 1). Thus, after the regression analysis, a quadratic effect was observed for both additives, CaO or urea (Figure 4).

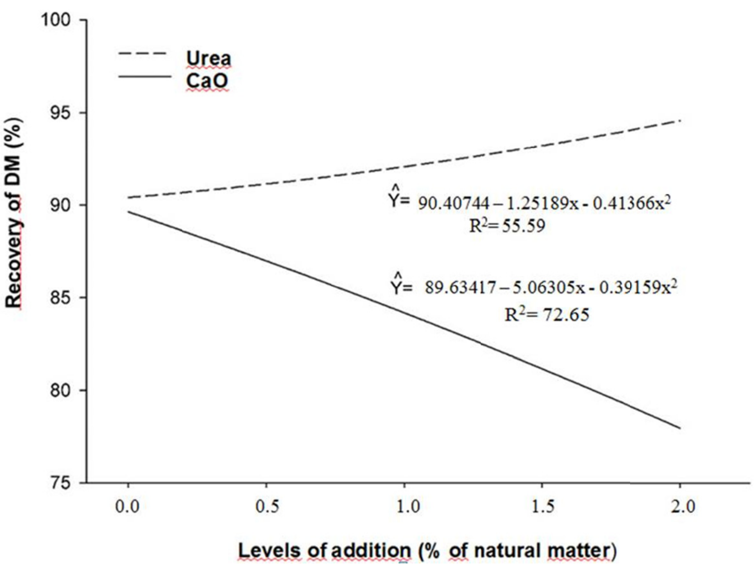

Figure 4. Recovery of DM (%) of by-product silages from sweet corn processing as a function of CaO or urea addition levels

The total loss of DM, in the silage treated with CaO, had an inadequate fermentation profile, resulting in pH values above the ideal range and higher losses by gases. Therefore, the CaO concentrations used were not efficient for the conservation of DM of the silages, presenting a mean reduction in the DM recovery of 10.15% in contrast to the control silage. The silage additive, urea, had a better fermentation profile, with the stabilization of the pH in a range suitable for conservation, positively affecting the loss in the form of gases, total loss of DM and, thus, offered a higher DM recovery. The level of 2.0% in the natural matter presented the highest DM recovery (97.25%) in relation to the control silage (91.40%).

Therefore, the results indicate that CaO as an additive is not recommended for the control of fermentation during the ensiling of sweet corn by-products. On the other hand, the inclusion of urea at all levels was effective in the fermentation control leading to lower DM losses. In this sense, the level of 2.0% of urea in the natural matter is recommended.

4. Conclusion

The CaO additive was not efficient in reducing fermentation losses and preserving silage. However, urea was efficient in the recovery of dry matter of silage sweet corn.

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