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Soybean hulls inclusion on silage of wet brewery waste

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ABSTRACT. This study aimed to evaluate the effects of soybean hulls inclusion in the silage of wet brewery waste. The experimental design was randomized in block, where the treatments were constituted by four levels of soybean hulls on the silage (0, 15, 25, and 35%), with three (silos) replicates per treatment. All data collected were subjected to ANOVA and subsequent polynomial regression at 5%. Soybean hulls inclusion caused a linear increase ($p < 0.05$) in the pH, dry matter, acid detergent fiber, neutral detergent fiber and total carbohydrates content of the silage. This inclusion also caused a significant reduction ($p < 0.05$) in the effluent losses and percentages of crude protein, fats, hemicellulose, non-fibrous carbohydrates and total digestible nutrients. Thus, it was concluded that soybean hulls can be used as an additive in the silage of wet brewery waste. Up to 35% of inclusion, there was a significant reduction in the effluent losses, a little increase on pH and enrichment of nutritional content, especially in the dry matter.

Keywords: additive; dry matter; nutrients; pH; soybean by-product.

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Introduction

A wide range of agro-industrial by-products are available in large quantities which have considerable nutritional potential to use in livestock (Senthilkumar et al., 2010; Ferreira et al., 2011; Patra & Yu, 2013). Alternative regional foods (co-products or by-products) from the agribusiness, from grain crops, fruit and fruit processing companies, biofuel industries (alcohol and mainly biodiesel) have been widely used in the feeding of ruminants in various aspects (value nutrition and digestibility of food, such as performance (consumption, weight gain and feed conversion), ruminal and blood parameters of animals, the production and quality of meat or milk, and the economic viability of this use (Beigh, Ganai, & Ahmad, 2017; Zambom et al., 2017).

Wet brewery waste is a typical example of alternative food, being used in diets for ruminants due to its high nutritional content, especially energy and protein, and great availability along the year for a low cost, which may minimize the costs with animal feeding (Souza et al., 2012). This food is a by-product of brewery industry which uses malted barely grains as feed stock. When grain is fermented to produce ethanol, primarily the starch is utilized, leaving behind a protein rich residue. In the feeding of ruminants, wet brewery waste can be used as a protein concentrate (23 to 30% crude protein), insoluble and of low degradability, constituting as a protein source, passing through ruminal degradation and being absorbed directly in the intestine (Orr, Henley, & Rude, 2008; Albuquerque et al., 2011; Faccenda et al., 2017; Halmemies-Beauchet-Filleau et al., 2018).

However, the wet brewery waste presents a low dry matter content (ranging from 9 to 30%), which represents an expressive limiting factor for its effective use, causing problems for transport, storage and preservation of this by-product (Geron et al., 2007). The high moisture content and storage conditions of the wet brewery waste under aerobic environment, commonly used on the farms, provide ideal conditions for the development of microorganisms, mainly filamentous fungi (Souza et al., 2012). These fungi promote the degradation of waste' nutrients and can produce toxins that affect the animal metabolism. They can utilize lactic acid and sugars, competing with lactic acid bacteria at the start of the fermentation process, forming ethanol, which causes a loss in the dry matter content and has no useful properties for the preservation of the silage (Muck, 2010; Souza et al., 2012).

Previous studies pointed that the use of nutrient-rich additives (usually higher than 80%) can enable the absorption of moisture, increasing the dry matter content of the ensiled material. Naturally, this increase on dry matter may promote a significant improvement in the chemical composition of the produced silage (Zopollatto, Daniel, & Nussio, 2009; Aliyu & Bala, 2011; Souza et al., 2012; Carrera et al., 2012; Souza, Goes, Silva, Yoshihara, & Prado, 2015; Cardoso et al., 2016; Chanie & FieVez, 2017). It is important to mention that silage additives are natural or industrial products added in determinate quantities to the silage mass with the purpose to improve nutrient composition of silage, to reduce storage losses by promoting rapid fermentation, to reduce fermentation losses by limiting extent of fermentation, and to improve bunk life of silage (increase aerobic stability) (Yitbarek & Tamir, 2014).

In this sense, soybean hulls are a by-product from the soybean processing industry, where the soybean is de-hulled leaving a highly digestible fibrous feed. The soybean hulls present a low lignin content and large proportion of potentially digestible fiber, being very used as primary ingredient in ruminant diets. Many studies have demonstrated the advantages of using soybean hulls as an energy source for ruminants in replacement of corn, as long as it is supplied together with effective fiber sources to reduce the rate of passage and enable ruminant fermentation (Bastos et al., 2015; José Neto et al., 2017; José Neto et al., 2019). Replaces the corn of the ruminant diet with soybean hulls, without changing the quality of animal performance, requires an order of 75%, better digestibility and energy value of the diet, maintaining in certain occasions the economic viability (Alcalde et al., 2009; Gentil et al., 2011).

What is scarce as information about the brewery residue with potential for exploitation in the feeding of animals in the form of silage and its effect on the fermentative process of silage with additive, aiming to evaluate the effect of increasing levels of selection of soybean hulls on silage of wet beer waste. Considering the above, the objective of this study was to evaluate the effect of increase levels of soybean hulls inclusion on the silage of wet brewery waste.

Material and methods

The study was conducted in the facilities of Forage and Pasture Laboratory of Federal University of Amazonas (Manaus, Amazonas State, Brazil) and Experimental Farm of Federal University of Amazonas (Manaus – Highway BR 174, Amazonas State, Brazil). The climate is characterized as hot and humid tropical, being limited to winter (rainy season), from December to June, and summer (dry season) from July to November.

The experimental design was randomized in block, where the treatments were constituted by four inclusion levels of soybean hulls on the silage (0, 15, 25, and 35%). Experimental silos (50 cm of height per 10 cm of diameter) with wooden lids were used, being three silos per treatment where each silo was considered a replicate. The silos were stored and sealed in a place protected of environmental conditions influence.

The wet brewery waste was obtained from Batuta brewery© (Manaus, AM, Brazil). The soybean hulls were obtained from Agrominas© (Manaus, Amazonas State, Brazil). The proportions of each material were individually calculated based in their natural matter content, being these distributed in the silos. Samples of each material were collected for individual analysis of chemical composition. Each silo was individually loaded, compacted, and sealed, presenting an average weight of 4 kg, without use of inoculants.

After 30 days, silos were opened in order to calculate the effluent losses (Schmidt et al., 2011), and measured the pH (Wilson & Wilkins, 1972). At the opening of the silos, the upper layer (approximately 10 cm) was discarded due to the possible presence of fungi and molds. 350 g of silage samples were collected in each period to evaluate the dry matter (%), organic matter (%), ashes (%), crude protein (%), fats (%), neutral detergent fiber (%), acid detergent fiber (%), hemicellulose (%), total digestible nutrients (%), and non-fibrous carbohydrates (%) according to methods described by Van Soest, Robertson, and Lewis (1991), and Schmidt et al. (2011).

All data collected in this study were analysed using the GLM procedure of SAS (2008) and estimates of treatments were firstly subjected to ANOVA and a subsequent polynomial regression. Results were considered significant at $p \leq 0.05$.

Results and discussion

Each feedstuff used to produce the silage in this study presented an individual chemical composition similar to those observed in previous studies (Aliyu & Bala, 2011; Bastos et al., 2015; Chanie & FieVez, 2017), where wet brewery waste presented a low dry matter content, and soybean hulls a high dry matter content.

However, both feedstuffs presented high organic matter content (Table 1). These studies also reported a high nutritional value of the soybean hulls, which may enable the production of a silage with good quality. Consequently, the low dry matter concentration of wet brewery waste result in a low osmotic pressure, permitting the development of microorganisms that break down sugars, lactic acid, proteins, and amino acids, transform these biomolecules in butyric acid, acetic acid, ammonia, carbonic gas, and starches which result insignificant losses and a good environment to silage production (Zanine et al., 2010).

Table 1. Chemical composition of feedstuffs used to produce the silage.

Chemical composition (%)	Wet brewery waste	Soybean hulls
Dry matter	21.55	91.03
Crude protein	39.52	11.33
Etheral extract	5.88	6.26
Organic matter	96.05	98.06
Ashes	3.95	1.94
Neutral Detergent Fiber	47.27	50.20
Acid Detergent Fiber	20.81	25.05
Hemicellulose	26.96	25.15

The use of soybean hulls may cause an effective increasing in the nutrients content of wet brewery waste silage, especially due to soybean hulls may provide an increase in the dry matter. It is important to mention that soybean hulls are a natural energy source for ruminants, replacing the corn, and acting on passage rate and ruminant fermentation (Bastos et al., 2015). For ruminants, soybean hulls have an energy value of 74 to 80% of corn for feedlot animals. If this energy value is extrapolated to the horse, soybean hulls would have 2.84 to 3.07 Mcal DE kg^{-1} of dry matter or slightly less than the energy value of oats (3.20 to 3.36 Mcal DE kg^{-1} of dry matter) (Ott & Kivipelto, 2002).

Like grasses, the main limiting factor for the production of a wet brewery waste silage with good quality is a low dry matter content. The high moisture of wet brewery waste tends to limit its utilization on farms distant from the brewing industry, because the very difficult to transportation and storage. And during the ensilage process, a secondary fermentation may occurs caused by bacteria, especially *Clostridium*, generating nutrient losses and effluents production (Geron et al., 2010; Imaizumi, Batistel, Souza, & Santos, 2015; Faccenda et al., 2017). In this sense, moisture-absorbing additives are an important tool to minimize the effects of low dry matter during the ensilage process (Aliyu & Bala, 2011; Negrão et al., 2016; Dias, Cândido, Furtado, Pompeu, & Silva, 2019).

Wet brewery waste results presented a great crude protein content when compared to soybean hulls (Table 1). According to Souza et al. (2012), Thomas, Hersom, Thrift, and Yelich (2016), and Chanie and Fievez (2017), the wet brewery waste is a good source of protein with a crude protein content that ranges from 25 to 34%. Other studies also pointed that this protein is mainly placed in the germ portion of the spent grain and is digested to a partial amount in the rumen and to a greater amount in the small intestinal tract (Chanie & Fievez, 2017). This variable denotes the nitrogen that is bound to the cell wall of the silage, which renders it unavailable throughout the digestive tract of the animal. However, the observed values do not compromise the quality of the silage (Santos et al., 2013).

The increasing inclusion of soybean hulls in the silage of wet brewery waste provided more alkaline pH ($p < 0.05$) and a significant reduction ($p < 0.05$) in the effluent losses. Effluent losses presented a quadratic effect ($Y = 2.4x^2 - 15.31x + 24$; $R^2 = 0.95$), where the production of effluents reduced according to the increase of levels of soybean hulls in the silage. pH presented a positive linear effect ($Y = 0.18x + 3.225$; $R^2 = 0.99$), where the pH increased according to the increase of levels of soybean hulls in the silage (Table 2).

Table 2. Effluent losses and pH of the silage of wet brewery waste with increasing levels of soybean hulls.

Variables	Inclusion levels of soybean hulls				Effect	CV (%)
	0%	15%	25%	35%		
Effluent losses (%)	11.50	1.75	0.90	0.75	Q	3.45
pH	3.38	3.62	3.77	3.93	PL	1.80

[1]CV – Coefficient of Variation; Q – Quadratic; PL – Positive Linear effect.

These results indicate a reduction in the activity of lactic acid bacteria and, consequently, lower production of lactic acid. In this sense, this little increase in pH was sufficient to reduce fermentative losses of effluents.

However, in the results of this study the pH was considered low in all silages evaluated, and even with a little increased in the pH due to inclusion levels of soybean hulls, the results of pH obtained indicating a good fermentative quality of the silages. Previous studies reported that lactic acid is not a good inhibitor to fungi and yeast activity and also serves as a substrate for its metabolism (Silva, Pedreira, Figueiredo, Bernardinho, & Farias, 2010). Unfortunately, lactic acid bacterial fermentation rarely lowers pH sufficiently and produces enough acetic acid to prevent yeasts and molds from growing in silage (Muck, 2010). According to Schmidt et al. (2011), under anaerobic conditions, fungi and yeast may develop at a lower pH when have soluble carbohydrates available in the medium.

In environmental aspect, it is important to mention that the successful use of additives to silage production depends on the growth ability of the bacteria, presence of adequate substrate, and population of bacteria in proportion to the silage mass. Additives with great dry matter content present several advantages to use in silages, especially due to the main ingredient used to silage production presents low dry matter (Yitbarek & Tamir, 2014; Silva, Jobim, Poppi, Tres, & Osmari, 2015; Grant & Ferraretto, 2018). According to Weiss and Underwood (2009), the incorporation of easily fermentable feed ingredients such as sugar or molasses to low dry matter sugar-limited tropical forages is a way to improve silage fermentation. To optimize their effectiveness by avoiding effluent losses they have to be used in relatively high rates (aiming a dry matter content > 25% of the mixture) and adequately mixed.

Generally, recommended moisture contents vary based on the type and dimensions of silos as well as the crop. A general recommendation to minimize effluent production is that crop moisture contents should not exceed 70-75% for bunker silos and 60 and 65% for tower silos. Silage effluent management has historically focused on minimizing its production, which has the added benefit of reducing dry matter losses, thus conserving fodder quality (Faulkner, Zhang, Geohring, & Steenhuis, 2011; Gebrehanna, Gordon, Madani, VanderZaag, & Wood, 2014; Gallo et al., 2015).

Gebrehanna et al. (2014) also reported that during the ensilage process, effluents (or leachate) are produced according to the moisture content of the ensiled crop, and crops with high moisture content tends to produce more effluents. Normally, effluent release during silage making represents a loss of silage dry matter, and a reduction in the value of the silage as feed. These concerns motivated research aimed at reducing effluent production and release to conserve crop quality.

The increase inclusion of soybean hulls in the wet brewery waste caused a linear increase ($p < 0.05$) on dry matter ($y = 7.198x + 14.59; R^2 = 0.99$), acid detergent fiber ($y = 4.571x + 12.90; R^2 = 0.89$), and total carbohydrates ($y = 2.412x + 70.18; R^2 = 0.92$). However, there was also a significant linear reduction ($p<0.05$) on crude protein ($y = -1.385x + 16.875; R^2 = 0.85$), fats ($y = -1.149x + 9.93; R^2 = 0.95$), hemicellulose ($y = -2.952x + 32.005; R^2 = 0.86$), and total digestible nutrients ($y = -4.212x + 79.935; R^2 = 0.97$) (Table 3).

Table 3. Chemical composition of the silage of wet brewery waste with increasing levels of soybean hulls.[1]

Variables	Inclusion levels of soybean hulls				Effect	CV (%)
	0%	15%	25%	35%		
Dry matter	21.88	29.19	35.50	43.77	PL	2.38
Crude protein	14.35	15.96	12.43	10.91	NL	16.59
Fats	9.08	7.19	6.47	5.49	NL	4.27
Organic matter	96.80	96.87	96.51	96.52	ns	0.29
Ashes	3.20	3.13	3.49	3.48	ns	8.33
Neutral detergent fiber	48.32	43.71	53.21	53.35	Q	14.28
Acid detergent fiber	16.33	22.42	29.28	29.28	PL	15.22
Hemicellulose	32.00	21.29	23.93	21.28	NL	14.33
Total digestible nutrients	76.18	71.43	66.09	63.92	NL	4.28
Total carbohydrates	73.38	73.72	77.62	80.12	PL	11.72
Non-fibrous carbohydrates	25.06	30.02	24.41	26.77	Q	11.26

[1]Results on basis of dry matter; PL – Positive Linear effect; NL – Negative Linear effect; ns – non significant; CV – Coefficient of Variation.

Neutral detergent fiber ($y = 1.1875x^2 - 3.4785x + 49.437; R^2 = 0.76$) and non-fibrous carbohydrates ($y = -0.65x^2 + 3.202x + 23.435; R^2 = 0.90$) content presented a quadratic effect ($p < 0.05$) where the higher inclusion of soybean hulls on silage caused a great increase on neutral detergent fiber content and reduction on non-fibrous carbohydrates content (Table 3).

These results indicated that increase levels of soybean hulls in the silage of wet brewery waste may promote a significant effect on its chemical composition, especially on dry matter and its main nutrients. Monteiro, Abreu, Cabral, Ribeiro, and Reis (2011), from them obtained results, reported that the use of soybean hulls, as other traditional additives, may provide the minimum dry matter content required to obtain a silage with good quality. Ferrari Junior and Lavezzo (2001) also commented that the use of additives in the silage may provide a substantial increase in nutrient content, especially protein, carbohydrates, and fats. In addition, Miron et al. (2001) reported that carbohydrates, predominantly polymers of glucose, makeup approximately 80% of the dry matter in soybean hulls and that most of these carbohydrates (75%) derive from polysaccharides recovered in the neutral detergent fiber fraction.

According to Queiroz, Arriola, Daniel, and Adesogan (2013) and Moriel et al. (2016), the main purpose to use of additives in silage is the control of preservation process so that by the time of feeding it has retained as many of the nutrients as possible and to ensure that the growth of lactic bacteria predominates during the fermentation process, producing lactic acid in quantities high enough to ensure a good silage. Additives are used to improve nutrient composition of silage, to reduce storage losses by promoting rapid fermentation, to reduce fermentation losses by limiting extent of fermentation, and to improve bunk life of silage (increase aerobic stability) (Yitbarek & Tamir, 2014).

Thomas et al. (2016) reported that the chemical characteristics of wet brewery waste vary according to its processing form. This is primarily due to limited drying capabilities of breweries and daily batches being compiled into one composite batch for removal at the end of a production week. The varying physical composition of wet brewery waste becomes important to consider when assessing the feasibility of silage production (Souza et al., 2012; Thomas et al., 2016; Chanie & Fievez, 2017). The blending wet brewery waste with other feeds such as soybean hulls results in an increased dry matter and increases the shelf-life by a small number of days (Thomas et al., 2016).

However, even having an increase on dry matter, some nutrients content decreased by increase inclusion levels of soybean hulls in the silage. Naturally, wet brewery waste and its silage tend to present a high protein content, and good fat content and total digestible nutrients (Thomas et al., 2016; Chanie & Fievez, 2017), but the inclusion of additives in the silage production may reduce the concentration of these nutrients by effluent losses during ensilage as observed in this study.

Conclusion

It was concluded that soybean hulls may be used as an additive in the production of silage of wet brewery waste. Up to 35% of inclusion, there was a significant reduction on effluent losses, a little increase on pH, and enrichment in nutritional content, especially dry matter.

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