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Use of by-products in a total mixed ration silage

Uso de subprodutos na silagem de ração total misturada

Daison Henrique Marocco[1]; Patrick Favero[1]; Rodrigo Guralski[1]; Clovisnei Basi[2]; Wilson Zacaron[2]; Gabriela Solivo[1]; Claiton André Zotti[3]*

Highlights:

Wet by products as wet brewery wastes and fresh orange pulp instead of dry (soybean hull) decreases dry matter of the total mixed ration silage.

Wet brewery wastes and fresh orange pulp increased dry matter losses and effluents of total mixed ration silage.

Adding soybean hull in the total mixed ration silage increased the aerobic stability and density.

Abstract

The objective of this study was to evaluated fermentation losses and silage quality with the addition of different by-products in TMR. A completely randomized design was used with four treatments: Control (CTL, with hay, corn silage, cracked corn, soybean meal, wheat bran and minerals); CTL plus the addition of fresh orange pulp (FOP); CTL plus soybean hulls (SBH) or CTL plus wet brewery wastes (WBW), with six replicates. The ingredients were mixed and ensiled in 24 PVC experimental silos. After 56 days of ensiling, fermentation losses (effluents, dry matter and gases), and the TMR silage pH and chemical composition were analyzed; aerobic stability was evaluated over seven days after the silos were opened. Lower dry matter ($P \leq 0.0001$) was observed in TMR ensiled with wet (WBW and FOP) compared to dry (SBH) by-products. Greater ADF ($P = 0.031$) was observed in SBH when compared to others by-products. WBW and FOP increased dry matter ($P \leq 0.0001$) and effluent losses ($P \leq 0.0001$) when compared to CTL and SBH. SBH treatment remained stable after 176-hour, which differ ($P = 0.0015$) compared with the other treatments (range from 94.5 to 99 hours of exposure to air). The density (kg DM/m^3) changed ($P \leq 0.0001$) among treatments. The inclusion of SBH in TMR silages had the greatest density, followed by CTL, WBW and FOP. The density was negatively correlated with DM losses (r= - 0,81; $P \leq 0.0001$). The pH differ ($P = 0.003$) among treatments. Highest pH of TMR silage was observed for SBH (3,67) and the lowest (3,56) for FOP. Soybean hulls successful improved aerobic stability and density, whereas aerobic stability and density were decreased and fermentation losses increased when fresh orange pulp and wet brewery were used. Little effects on chemical composition were observed, thereby agro-industrial by-products can be used in TMR silages as long as there is adequate product availability and pricing.

Key words: Aerobic stability. Fermentation losses. Total mixed ration.

[1] Discentes do Curso de Graduação em Zootecnia, Universidade do Oeste de Santa Catarina, UNOESC, Xanxerê, SC, Brasil. E-mail: daisonhm@hotmail.com; tikifavero@hotmail.com; rodrigo.guralski@hotmail.com; gabriellasolivo@gmail.com

[2] Mestrando do Programa de Pós-Graduação em Sanidade e Produção Animal, UNOESC, Campus II, Xanxerê, SC, Brasil. E-mail: c.basi@unoesc.edu.br; wilson.zacaron@unoesc.edu.br

[3] Prof., Departamento de Zootecnia, Programa de Pós-Graduação do Mestrado em Sanidade e Produção Animal, UNOESC, Xanxerê, SC, Brasil. E-mail: claiton.zotti@unoesc.edu.br

* Author for correspondence

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Resumo

Objetivou-se avaliar as perdas fermentativas e qualidade química da ração total misturada (TMR) ensilada com a adição de diferentes subprodutos da indústria. Um delineamento inteiramente casualizado com quatro tratamentos foi utilizado: CTL (Feno, silagem de milho, milho quirera, farelo de soja, farelo de trigo e mistura mineral), FOP (CTL com adição de bagaço de laranja *in-natura*), ou SBH (CTL com adição de casca de soja) e WBW (CTL com adição de resíduo úmido de cervejaria), utilizando-se seis repetições por tratamento. Os ingredientes foram misturados e armazenados em 24 silos experimentais de PVC. Após 56 dias de armazenamento, as perdas fermentativas (efluentes, perda de matéria seca e produção de gases), e o pH, composição bromatológica e estabilidade aeróbica durante 7 dias das silagens de TMR foram mensuradas. Menor teor de MS ($P \leq 0,0001$) foi observado para TMR ensiladas com resíduos úmidos (WBW e FOP) comparado com SBH. O uso de SBH apresentou maior teor de FDA ($P = 0,031$) comparado aos demais tratamentos. Adição de WBW e FOP aumentou as perdas de matéria seca ($P \leq 0,0001$) e efluentes ($P \leq 0,0001$) em relação a CTL e SBH. O tratamento SBH não apresentou quebra de estabilidade (176 horas), diferindo ($P = 0,0015$) em relação aos outros tratamentos (variação de 94,5 a 99 horas de exposição ao ar). A densidade (kg MS/m^3) foi diferente ($P \leq 0.0001$) entre os tratamentos. A inclusão de SBH na silagem de TMR apresentou as maiores densidades, seguido pelo tratamento CTL, WBW e FOP. A densidade teve correlação negative com as perdas de MS (r= -0,81; $P \leq 0.0001$). O pH diferiu entre tratamento ($P = 0,003$), sendo maior para CSC (3,67) e menor para BLI (3,56). O tratamento casca de soja apresentou a melhor estabilidade aeróbia e densidade, enquanto a estabilidade e densidade diminuíram e as perdas fermentativas aumentaram quando bagaço de laranja *in-natura* e resíduo úmido de cervejaria foram utilizados. Apesar das diferenças na composição das TMR ensiladas, a adição dos subprodutos pode ser uma opção adequada desde que haja disponibilidade e preço viável.

Palavras-chave: Estabilidade aeróbica. Perdas fermentativas. Ração total misturada.

The genetic improvement of dairy cows, combined with the use of technology in sophisticated production systems, require to adequate diet, with quality and quantity balanced diets. To avoid the selection of ingredients and promote an adequate and homogeneous consumption of dry matter the use of total mixed ration (TMR) is an alternative to dairy production system. Failures in preparation, loading, mixing time and shape or distribution, may directly impact the quality of feed offered, preventing the achievement of desired indices. Thus, TMR silage has successfully been tested due to its advantage of provide uniform feed and balanced diet to the animals, and high aerobic stability (Wang & Nishino, 2013; Weinberg et al., 2011).

Because the production seasonality of many by-products, combined with the difficulty of storage for prolonged periods, the TMR silage with by-products might be an efficient form of storage. The great availability of valuable residues of agro-industrial by-products (specially in Brazil) is the main motivation of storage feed as TMR silage (Daniel, Bueno, Lazzari, & Jobim, 2019). Some studies have shown that TMR silage provides good production of lactic acid without increases effluent losses (Restelatto et al., 2019), and increases fibrolytic bacteria concentration when compared with ensiled TMR (Uyeno et al., 2016; Gusmão, Danés, Casagrande, & Bernardes, 2018). The objective was to evaluate the inclusion of different by-products on the chemical composition and fermentation traits, storage losses, as well as the aerobic stability of TMR silages.

The experiment was carried out at the Laboratory of Animal Nutrition of the University of Western of Santa Catarina (UNOESC), Campus I, Xanxerê, State of Santa Catarina. The ingredients were purchased from a commercial farm and mixed by hand. The diet was ensiled in polyvinyl chloride experimental silos, 25 cm height and 10 cm diameter (1.963-L capacity) and manually compacted. Twenty-four experimental silos were filled (six replicates per treatment), identified, sealed, weighed and stored at room temperature (23.3 ± 1.5 ºC) for 56 days.

Four treatments were used: Control (CTL, with hay, corn silage, cracked corn, soybean meal, wheat bran and minerals); CTL plus the addition of fresh orange pulp (FOP); CTL plus soybean hulls (SBH) or CTL plus wet brewery wastes (WBW) (Table 1). These four ensiled diets were formulated to meet or exceed the National Research Council [NRC] (2001) requirements of lactating cow, producing 32 kg day milk yield, 3.5% fat milk, with 160 days in milk, containing 16% of crude protein and 67% of total digestible nutrients.

The experimental silos were opened and weighed to calculate dry matter losses, effluents, and gases losses, as showed by Dantas et al. (2014). The silos were opened and spoiled TMR silage was discarded and the remainder was sample for the analysis. One subsample from each silo was pre-dried in a forced air oven at 55 ºC for 72 hours, then removed and weighed, followed by milling in a Wiley-type mill, with 1 mm mesh sieve. The pre-dried and ground samples were submitted to the oven at 105 ºC to obtain the dry matter, and later to obtain ash content, and the crude protein (CP), determined using the micro-Kjeldahl method. These methods are described in Silva and Queiroz (2009). Determination of neutral detergent fiber (NDF), and acid detergent fiber (ADF) concentrations were performed as described by Giombelli, Roscamp, Gomes, Zotti and Schogor (2019).

Approximately one kg of ensiled TMR was divided into three plastic buckets per treatment and keep under room temperature to determine the aerobic stability. A datalogger was placed in the mass and automatically recorded temperature at 30-minute intervals for seven consecutive days of aerobic exposure. The criterion used to determine the end of aerobic stability was the time when the ensiled TMR reached an internal temperature 3 °C above room temperature as described by Gusmão et al. (2018). The silage pH was determined using a digital potentiometer by the dilution of 25 grams of fresh sample in 225 mL of distilled water (Kung, Grieve, Thomas, & Huber, 1984).

Table 1
Chemical composition of feeds ingredients and total mixed rations ensiled with wet or dry agro-industrial by-products (treatments)

Ingredients	Chemical composition[1]					Treatment[2]			
	DM	CP	NDF	ADF	Ash	CTL	SBH	FOP	WBW
Hay (Tifton 85)	88.6	12.1	73.8	40.7	8.9	6.0	5.5	6.0	6.0
Corn silage	27.1	7.25	52.2	37.3	5.43	61.4	57.5	59.0	59.0
Cracked corn	87.4	7.91	11.7	3.43	1.42	6.0	5.0	4.0	5.0
Soybean meal	88.0	44.3	26.6	11.6	6.53	19.6	19.0	20.0	17.7
Wheat bran	88.1	16.4	33.4	12.4	4.30	5.0	5.0	4.0	4.0
Commercial mineral[3]	100	-	-	-	100	2.0	2.0	2.0	2.0
Soybean hulls	89.0	11.8	67.8	55.0	4.56	-	6.0	-	-
Wet brewery wastes	16.7	21.3	64.0	25.9	5.76	-	-	5.0	-
Fresh orange pulp	19.0	6.90	22.0	17.4	3.8	-	-		6.3

[1]Dry matter (DM), Crude protein (CP), Neutral detergent fiber (NDF), Acid detergent fiber (ADF).
[2]Control (CTL); with soybean hulls (SBH); with fresh orange pulp (FOP); with wet brewery wastes (WBW).
[3]Guaranteed levels: calcium 190 g/kg, phosphate 60 g/kg, sulfur 20 g/kg, magnesium 20 g/kg, potassium 35 g/kg, sodium 70 g/kg, cobalt 15 mg/kg, copper 700 mg/kg, chromium 10 mg/kg, iron 700 mg/kg, iodide 40 mg/kg, manganese 1600 mg/kg, selenium 19 mg/kg, zinc 2500 mg/kg, vitamin A 200000 IU, vitamin D3 50000 IU, vitamin E 1500 IU, fluoride 600 mg/kg.

A completely randomized design was used with four treatments and six replications. The following statistical model was used for the analysis: $Yij = \mu + Ti + \varepsilon ij$; where Yij = the response variable of interest, μ = the overall mean, Ti = effect of treatment (CTL, SBH, FOP and WBW) and εij = the residual error. Data were subjected to ANOVA and means differences were compared using the Tukey test at 5% significance. Trends were discussed at $P \leq 0.10$. Statistical analyses were performed using the SAS statistical program (SAS University Edition).

The inclusion of SBH showed greatest ($P < 0.0001$) DM of the TMR silage, while wet (WBW and FOP) had intermediary and CTL the lowest DM content (Table 2), which indicates the beneficial use of SBH in TMR silage and higher concentrations of nutrients. Greater ADF ($P = 0.031$) was observed in SBH when compared to other by-products, which is justified by the high ADF content present in SBH compared to the other by-products. A tendency of greater ($P = 0.06$) CP content to WBW compared with FOP and for NDF ($P = 0.08$) contents of SBH and WBW compared with CTL were observed. This occurred due to the great variation on composition of by-products utilization. For example, despite the high NDF content of SBH and WBW (67.8 and 64%, respectively), these by-product have high potential to meet energy requirements of dairy cattle. Smith et al. (2017) observed that the ruminal digestibility of NDF were 72.7% and 65.8%, respectively for SBH and WBW. Chemical composition of TMR silage was not differ for ashes ($P = 0.241$).

Greater dry matter ($P \leq 0.0001$) and effluent losses ($P \leq 0.0001$) were observed for WBW and FOP treatments when compared with CTL and SBH. Instead, gas losses ($P = 0.489$) was not different by treatments. The lower DM content of TMR silage in WBW and FOP treatments increased their losses, because DM and losses are factors directly related (Borreani, Tabacco, Schmidt, Holmes, & Muck, 2018). Fermentation losses are related to the population of microorganism in silage and lactic acid bacteria activity is essential to reduce such losses (Muck, 2013). Restelatto et al. (2019)

evaluated the effects of the microbial additives *L. buchneri* and *L. plantarum* on TMR silages ensiled for 15 or 60 days DM losses for treatment without microbial additives were described ranging from 0.5 to 1.4% DM.

There was pH effect when different by-products were used in TMR silage. The greatest pH o TMR silage was observed for SBH and the lowest for FOP. According to Tomich, Pereira, Gonçalves, Tomich and Borges (2003), the pH values below 4, combined with dry matter higher than 28%, inhibit the growth of undesirable bacteria, also yeasts and molds in silage. A rapid decrease in pH, below 4, is related to reduces protein breakdown, which is beneficial for quality of silage and for the animal (Daniel et al., 2019). In our study although different ingredients sources were used, all TMR showed pH within the recommended range. However, the ideal TMR silage pH depends on silage DM, ingredients and ensiling periods (Restelatto et al., 2019).

Regarding the aerobic stability of TMR silage, the SBH treatment remained stable during the 176-hour observation period, whereas the other treatments presented temperature increases 3 °C above room temperature after 90 hours of exposure to air. Aerobic stability is an indicator of silage losses (during the storage and feed-out). During the feed-out, accelerated growth of spoilage organisms (yeasts) results in high temperatures and nutrients and DM losses, leading to increased silage deterioration (Bernardes et al., 2018). In agreement to our results, Weinberg et al. (2011) and Wang and Nishino (2013) also observed that TMR silage temperature remained stable, without aerobic deterioration, for seven days. Gusmão et al. (2018) reported times from 75 to 127 hours. Even in the summer high aerobic stability of ensiled TMR is reported for up to 5.5 days (132 hours).

The density (kg DM m^{-3}) changed ($P \leq 0.0001$) among treatments. The inclusion of SBH in TMR silages had the greatest density, followed by CTL, WBW and FOP. In the present study, the density was negatively correlated with DM losses (r= -0,81; $P \leq 0.0001$). Therefore, density is crucial for high-quality TMR silages, because the oxygen allows aerobic microorganisms to consume readily available carbohydrates and acids within the silage, causing DM loss (Borreani et al., 2018). Other study (Restelatto et al., 2019) that evaluated TMR silage reported density of 350 kg DM m^{-3}, with an average DM of 41.8%.

The ensiling process can alter the composition of the TMR silage, providing gains in digestibility of some nutrients such as protein and starch, even when fermentation losses occur (Miyaji & Nonaka, 2018). The addition of various ingredients and by-products and their interactions result in products of good quality and homogeneity. Therefore, future trials should elucidate the microbiology and fermentation pattern of TMR silage when by-products are used. These finds will contribute to better understand the potential of these ensiled feed to ruminants.

Table 2
Chemical composition, fermentation variables and losses total mixed ration TMR silages using wet or dry agro-industrial by-products (treatments)

Variable	Treatments[1]				SEM	P-value
	CTL	SBH	WBW	FOP		
	Chemical composition					
Dry matter, % of as fed	37.5 [b]	39.6 [a]	34.9 [c]	34.4 [c]	0.64	<0.0001
CP, % of DM[1]	16.3	15.9	16.6	15.0	0.24	0.06
NDF, % of DM[1]	35.2	40.0	40.03	37.9	0.81	0.08
ADF, % of DM[1]	21.7[b]	27.1 [a]	24.9 [ab]	24.4 [ab]	0.71	0.03
Ash, % of DM[1]	7.0	7.0	7.2	7.5	0.09	0.24
	Fermentation variables and losses					
Dry matter losses, %	1.01 [b]	0.74 [b]	1.55 [a]	1.65 [a]	0.02	<0.0001
Effluents, (%)	0.56 [b]	0.21 [b]	1.06 [a]	1.08 [a]	0.09	<0.0001
Gas, (%)	0.45	0.53	0.49	0.49	0.01	0.489
Aerobic stability (h)	99.0 [b]	176 [a]	96.2 [b]	94.5 [b]	12.7	0.0015
Density (kg DM m^{-3})	282.4 [b]	299.7 [a]	263.3 [c]	259.9 [d]	3.3	<0.0001
pH	3.59 [bc]	3.67 [a]	3.62 [ab]	3.56 [c]	0.01	0.003

[a-d] Means in the same row with different superscripts differ ($P \leq 0.05$).
[1] Dry matter (DM), Crude protein (CP), Neutral detergent fiber (NDF), Acid detergent fiber (ADF).
[2] Control (CTL); with soybean hulls (SBH); with fresh orange pulp (FOP); with wet brewery wastes (WBW).

In conclusion, soybean hulls successful improved aerobic stability and density, whereas aerobic stability and density were decreased and fermentation losses increased when fresh orange pulp and wet brewery were used. Little effects on chemical composition were observed, thereby agro-industrial by-products can be used in TMR silages as long as there is adequate product availability and pricing.

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