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PARÁMETROS FERMENTATIVOS Y VALOR NUTRICIONAL DE ENSILADOS DE AVENA CON GRANOS DE GIRASOL Y MAÍZ

FERMENTATIVE PARAMETERS AND NUTRITIONAL VALUE OF OAT SILAGE WITH SUNFLOWERS AND CORN GRAINS

Elia E. Araiza-Rosales[1], Francisco O. Carrete-Carreón[2], Faviola Ortiz-Robledo[3], Juan F. Sánchez-Arroyo[2] y Esperanza Herrera-Torres[3]*

[1]CONACYT-FMVZ, Universidad Juárez del Estado de Durango (UJED), Facultad de Medicina Veterinaria y Zootecnia, Durango, Durango, México. [2]UJED, Facultad de Medicina Veterinaria y Zootecnia, Durango, Durango; México. [3]Tecnológico Nacional de México, Instituto Tecnológico del Valle del Guadiana, Villa Montemorelos, Durango, México.

**Corresponding author* (hetoes99@yahoo.m.mx)

SUMMARY

One of the primary goals of livestock producers is to maintain forage quality at adequate levels that allow obtaining a good profit in milk production. A supplementation strategy could be silage with sources of fat and soluble carbohydrates that improve forage quality. The objective of this study was to evaluate the fermentative and nutritional quality of oat silage with ground corn and sunflower grain (SG) using three combinations of oat forage and ground corn (100-0, 95-5, 90-10) with three levels of sunflower grain (0, 5 and 10 %). The pH, N-NH_3, lactic acid, dry matter (DM), crude protein (CP), crude fat (CF), non-structural carbohydrates (NSC), *in vitro* digestibility of dry matter (IVDDM), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were evaluated in triplicate using 27 micro-silos. No significant Combination × SG level interaction was observed (P > 0.05). DM content was higher in T2 whereas CP concentration was lower in T6 (95-5-10) (P ≤ 0.05). The Combination × SG level interaction was significant for CF, ADF, lignin and IVDMD (P ≤ 0.05); however, such interaction was non-significant for NDF, pH, N-NH_3 and lactic acid (P > 0.05). The inclusion of SG when combined with oat forage and ground corn increases the nutritional value of the oat silage but does not improve the fermentative quality of the forage.

Index words: *Avena sativa*, fermentation, nutritive quality, silage, sunflower.

RESUMEN

Uno de los principales objetivos de los productores pecuarios es mantener la calidad del forraje a niveles adecuados que permitan obtener una buena ganancia en producción de leche. Una estrategia de suplementación pueden ser los ensilados con fuentes de grasa y carbohidratos solubles que mejoren la calidad del forraje. El objetivo del presente estudio fue evaluar la calidad de fermentación y nutritiva del ensilado de avena con maíz molido y grano de girasol (SG), mediante tres combinaciones de forraje de avena y maíz molido (100-0, 95-5, 90-10) y tres niveles de grano de girasol (0, 5 y 10 %). Se determinó el pH, N-NH_3, ácido láctico, así como materia seca (MS), proteína cruda (PC), grasa cruda (GC), carbohidratos no estructurales (CNE), digestibilidad *in vitro* de la materia seca (DIVMS), fibra detergente neutra (FDN), fibra detergente ácida (FDA) y lignina en los tratamientos por triplicado, empleando 27 microsilos. No se observó interacción significativa combinación × nivel de grano (P > 0.05). El contenido de MS fue mayor en T2 y la concentración de PC fue menor en T6 (95-5-10) (P ≤ 0.05). La interacción combinación × nivel de SG fue significativa para el contenido de GC, FDA, lignina y DIVMS (P ≤ 0.05); sin embargo, la interacción no fue significativa para pH y la concentración de FDN, N-NH_3 y ácido láctico (P > 0.05). La inclusión de grano de girasol cuando se combina con forraje de avena y maíz molido aumenta el valor nutritivo del ensilaje de avena pero no mejora la calidad fermentativa del forraje.

Palabras clave: *Avena sativa*, calidad nutritiva, ensilaje, fermentación, girasol.

INTRODUCTION

Northern Mexico has been experiencing extreme temperatures and dry seasons that lead to a reduction in forage production and nutritional quality. Under these production conditions, the use of additives emerges as an alternative in livestock feeding (Herrera-Torres *et al*., 2014). Additives improve the animal feed intake and productive performance (Garcés *et al*., 2004); thus, livestock farmers use the silage process for the conservation of forages. The silage process is carried out by acidification and fermentation of carbohydrates soluble in lactic acid and volatile fatty acids by lactic acid producing microorganisms under anaerobic conditions; in addition, it inhibits the growth of pathogenic microorganisms and allows the nutritional characteristics of forage to be preserved for later use (Wilkins *et al*., 1999). Oats is an important forage used in Northern Mexico, it is commonly used for silage as it requires less water for growth and is very useful for late planting when growing conditions do not justify the use of corn crops (Sánchez *et al*., 2014). Furthermore, oat forage has been shown to be a good forage source for ensiling; however, its metabolizable energy content is relatively low (Condori-Quispe *et al*., 2019). On the other hand, ground corn is an important ingredient for silage due to its energy content; consequently it is commonly used as an ingredient when ensiling forages (Moscoso-Muñoz *et al*., 2020; Ortiz *et al*., 2017). Sunflower is a crop that

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tolerates soil moisture deficit; this characteristic allows it to withstand the shortage of rains and prolonged droughts; in addition, sunflower grain (SG) is rich in crude protein and crude fat (mostly polyunsaturated free fatty acids), which confer the ability to SG of being used as additive (Basarab *et al*., 2008). Therefore, the objective of this study was to determine the effect of the addition of different proportions of ground corn and sunflower grains on fermentative and nutritional quality of oat silage.

MATERIALS AND METHODS

Study area

This study was carried out at Faculty of Veterinary Medicine and Zootechnics, Juárez University of the state of Durango, Mexico. The oat forage (cv. Cuauhtémoc) was randomly harvested from irrigated crops located nearby the Faculty area in Durango, Mexico. Sunflower grain (cv. Madero 31) and ground corn (cv. Caribu) were purchased at a local store. The chemical composition of the ingredients is presented in Table 1.

Preparation of micro-silos

Experimental micro-silos were prepared with different proportions of oat forage (OF), sunflower grain (SG) and ground corn (GC). Twenty-seven experimental micro-silos were prepared by mixing solely oat forage (T1), and oat forage with ground corn and sunflower grain (T2 to T9) as described in Table 2. Oat forage was harvested at late milk maturity stage (Rosser *et al.,* 2016). Subsequently, forage was cut to a particle size of 2 to 4 cm; afterwards, experimental micro-silos were hermetically sealed into plastic containers (19 L) for 30 d. Once the time elapsed, the silages were opened for analysis.

Experimental design and experimental unit

A completely randomized design was used under a 3 × 3 factorial arrangement with three mixtures of oat forage and ground corn, and three levels of sunflower grain, resulting in nine treatments with three replications, The experimental units were the micro-silos.

Silage fermentation analysis

Once the silages were opened, the following variables were evaluated: pH was measured according to the method described by Tobía *et al*. (2004) using a potentiometer (Model HI 83142, Hanna Instruments, Mexico City); lactic acid was evaluated according to Borshchevskaya *et al*. (2016); ammonia-nitrogen (NH_3-N) concentration was evaluated using the procedure proposed by Galyean (2010).

Chemical analyses

Samples of each experimental micro-silo were dried into a forced-air oven at 55 °C for 72 h, and ground to 1 mm particles using a Wiley mill (Arthur H. Thomas, Philadelphia, Pennsylvania, USA) and stored for further analyses. Dry matter and ash were determined by drying the samples according to procedures proposed by AOAC (2015). Crude fat (CF) was calculated by extracting fat using the soxhlet equipment as proposed by AOAC (1990). The CP concentration was calculated by determining the total nitrogen (N) content using the micro-Kjeldhal technique (Method 920.87; 5) and multiplied by a fixed conversion factor (6.25) according to AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin concentrations were determined following methods proposed by Van Soest *et al*. (1991). Non-structural carbohydrates (NSC) were estimated as the difference resulted from the equation NSC = [100 - (CP + CF + Ash FDN)]. *In vitro* dry matter digestibility (IVDMD) at 48 h was estimated in triplicate by incubating samples

Table 1. Chemical composition of oat forage, corn grain and sunflower grain used in the preparation of microsilos (g kg^{-1}).

	Oat forage	Corn grain	Sunflower grain
Dry matter	205	855	900
Crude protein	123.5	93.1	193
NDF	710.6	77.2	700.5
ADF	590.9	20.5	450.1
Ash	124.1	14.3	380
Lignin	25	10.3	150
IVDMD	581.7	705.5	604.3

NDF: neutral detergent fiber, ADF: acid detergent fiber, IVDMD: *in vitro* digestibility of dry matter

Table 2. Proportions of the experimental silages.

Treatment	Oat forage (%)	Ground corn (%)	Sunflower grain (%)
T1	100	0	0
T2	100	0	5
T3	100	0	10
T4	95	5	0
T5	95	5	5
T6	95	5	10
T7	90	10	0
T8	90	10	5
T9	90	10	10

of experimental micro-silos (DaisyII®, ANKOM Technology, Fairport, New York, USA) according to procedures described by the manufacturer.

Statistical analysis

The data were analyzed through analysis of variance using the GLM procedures of SAS version 6 (SAS Institute, 1989) using the model

$$yij = \mu + \tau i + \beta j + (\tau\beta)ij + £ij$$

where: yij is the response, μ is the mean, τi is the treatment effect, βj is the level of sunflower, $(\tau\beta)ij$ is the interaction effect and $£ij$ is the experimental error.

Means comparison was performed with the Tukey test declaring significant differences at $P \leq 0.05$; highly significant differences were declared at $P \leq 0.01$ and very highly significant differences at $P \leq 0.001$ (Equation 1).

RESULTS AND DISCUSSION

Table 3 shows the chemical composition of experimental silages. No significant interaction between OF-GC mixtures and SG level was observed ($P > 0.05$). DM content was lower in the mixture 95-5-10 ($P \leq 0.05$); however, contents of DM registered in this research are into acceptable values for silage of good quality (Mohd-Setapar, *et al*., 2012); these authors mentioned that silages should contain from 30 to 35 % of DM. Results of this study agree with those obtained by Apráez-Guerrero *et al.* (2012) who registered values of 28.78% in oat silage, whereas Ortiz *et al.* (2017) reported 20.4% in maralfalfa silage.

Interaction OF-GC × SG level was significant for protein content ($P \leq 0.05$; Table 3). The lower protein concentration was observed in treatment 95-5-10 ($P \leq 0.05$); however, the protein concentrations registered in this research are within the optimal range according to de Blas *et al*. (2010). Likewise, Van Soest (1994) mentioned that lower PC values (6-8 %) in the cattle diet can negatively affect ruminal nitrogen metabolism and feed intake. The protein content obtained in this study was higher than that registered by Abdelhadi and Santini (2006) in corn and sorghum silages (6.1 and 6.37 %, respectively), and by Jensen *et al.* (2005); meanwhile, Castillo *et al*. (2009) observed a protein content of 10.4 % in corn-bean silage.

Interaction OF-GC × SG level was very highly significant for CF content ($P \leq 0.001$; Table 3). The higher content of CF was observed in silages with sunflower grain. This may be related to the high oil content in SG (42 %) (McGuire and McGuire, 2000). These results indicate that fat content in oat forage is poor and silages are enriched by the addition of GC and SG in all treatments.

Interaction OF-GC × SG level was highly significant for NSC content ($P \leq 0.01$; Table 3). The inclusion of SG and GC increased the NSC concentration in silages, which improves energy content and fermentation rate (Amer *et al*., 2012). On the contrary, a dilution effect in metabolizable energy was observed when OF increased in experimental micro-silos due to the lower contents of NSC. Otherwise, the NSC values registered were lower than those obtained by Araiza-Rosales *et al*. (2013) in corn silages.

Interaction OF-GC × SG level was significant for IVDMD ($P \leq 0.01$; Table 3). The IVDMD increased with SG due to the lower degree of lignification of oat forage. Moreover, micro-silos with CG provided soluble carbohydrates which improved digestibility (Aragadvay-Yungán *et al*., 2015; Ortiz *et al*., 2017). Additionally, the treatment with the lowest NDF and lignin content has the lowest IVDMD; on the contrary, the higher the content of NDF and lignin, the higher the IVDMD. The digestibility of forage also plays an important role in animal production (Li *et al.,* 2014). It is worth mentioning that the IVDMD depends on physical characteristics of forage, especially the fiber content; low NDF and ADF contents lead to a rapid increase in digestibility of DM. This agrees with results obtained in this study and with those reported by Huhtanen *et al*., 2007 and by Zhang *et al*., 2016. Regarding to the fiber content in experimental micro-silos, no significant interaction OF-GC × SG level for NDF was observed (P > 0.05; Table 4); however, the values obtained for NDF are in an acceptable range for good quality forage (< 60 g kg DM^{-1}). These results may be explained by the increased hydrolysis of hemicellulose that occurs during silage fermentation. At this stage, pentoses are released and may be fermented into lactic and acetic acids (McDonald *et al*., 2002). Conversely, higher concentrations of NDF were registered by Britos *et al*. (2007) in pasture silage enriched with buttermilk.

Interaction OF-GC × SG level was highly significant (P ≤ 0.01; Table 4) for ADF content. The ADF concentration in all microsilos was higher than the optimum value (25 %) as reported by Phiri *et al*. (2007). The lignin content of SG was relatively high and it is reported to be within 20-25 % according to Taha *et al*. (2012); in addition, Kimiaeitalab *et al.* (2017) reported ADF contents of 70 %. Due to this, when SG is added an increase in ADF and lignin is observed in the experimental micro-silos; however, IVDMD was not affected by the addition of SG. This can be explained as a possible dilution effect that can be attributable to a reduction in oat forage and an increase in CG.

Interaction OF-GC × SG level was significant (P ≤ 0.01; Table 4) for lignin content. The lignin values registered in this study were higher than those reported by Castro *et al*. (2006) in silage of Tifton 85 (*Cynodon* spp.) pasture and star grass silage. Moreover, contents of ADF and NDF are 40 and 70 %, respectively.

pH and N-NH_3

Interaction between OF-GC × SG level for pH, N-NH_3 and lactic acid was not significant (P > 0.05; Table 5); however, the values determined in this study are within the optimal range recommended by Van Soest *et al*. (1991). Additionally, Evangelista *et al.* (2000) prepared silages with *Cyonodon* that presented pH values of 4.5 to 5.3 which are similar to those obtained in this study; low pH values avoid deterioration. The obtained values can be explained by the low content of soluble carbohydrates (Vu *et al.,* 2019) which promotes the production of lactic acid. These results agree with those reported by Aragadvay-Yungán *et al*. (2015) in sunflower silage.

On the other hand, the highest concentration of N-NH_3 was registered in silage with 10 % SG (100-0-10); this increase can be attributed to the presence of microorganisms capable of improving proteolysis when they adhere to the substrate due to a reduction in the fiber fractions (Berumen *et al*., 2015). Moreover, this parameter is an indicator of the catabolism of proteins and aminoacids (Junior *et al*., 2017). The results obtained in this study are similar to those reported by Zanine *et al*. (2010) in corn silage (14.6 %), but higher than those mentioned by Ortiz *et al*. (2017) in maralfafa silages.

Table 3. Chemical composition of experimental silage (g kg DM^{-1}).

Ratio OF-GC × SG (%)	DM (%)	CP (%)	CF (%)	NSC (%)	IVDMD (%)
100-0-0	30.4 ab	12.0 a	3.31 d	58.9 ab	51.5 c
100-0-5	32.97 a	11.8a	11.0 a	55.2 bc	59.8 c
100-0-10	28.4 ab	11.1a	10.8 a	54.5 bc	68.9 ab
95-5-0	29.8 ab	10.9 a	3.9 d	63.0a	64.8 b
95-5-5	28.9 ab	11.1 a	11.6 a	52.0 c	65.81 ab
95-5-10	23.7 c	8.5 b	9.7 ab	54.5 bc	70.87 ab
90-10-0	26.6 bc	11.5 a	5.6 c	56.4 bc	71.5 a
90-10-5	30.1 ab	10.8 a	5.8 c	57.3 b	69.6 ab
90-10-10	28.3 ab	11.9 a	10.4 a	54.2 bc	70.6 ab
SEM	0.40	0.19	0.21	0.32	0.55
OF-GC × SG	NS	*	***	**	**

Different letters within a column indicates significant differences (Tukey, P ≤ 0.05). *: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001, NS: non significant difference, DM: dry matter, CP. crude protein; CF: crude fat, NSC: non-structural carbohydrates, IVDMD*: in vitro* dry matter digestibility, SEM: standard error of the mean.

Table 4. Detergent fibers content of oat silages with different levels of ground corn and sunflower grain (g kg DM^{-1}).

Ratio OF-GC × SG (%)	NDF (%)	ADF (%)	LIG (%)
100-0-0	51.5 b	36.3 b	5.0 c
100-0-5	54.7 ab	42.9 a	6.9 bc
100-0-10	55.2 ab	43.6 a	10.7 ab
95-5-0	59.5 a	43.4 a	12.6 a
95-5-5	57.8 ab	39.0 ab	12.8 a
95-5-10	52.4 b	34.4 ab	10.8 ab
90-10-0	58.0 ab	33.3 b	14.8 a
90-10-5	55.3 ab	35.6 b	12.2 a
90-10-10	54.8 ab	32.6 b	13.36 a
SEM	0.39	0.41	0.32
OF-GC × SG	NS	**	**

Means with different letters within a same column indicates significant differences (Tukey, P ≤ 0.05). **: P ≤ 0.01, NS: non significant, SEM: standard error of the mean, NDF: neutral detergent fiber, ADF: acid detergent fiber, LIG: lignin.

Table 5. Fermentative parameters of oat silage with different levels of ground corn and sunflower grain (g kg DM^{-1}).

Ratio OF-GC × SG (%)	pH	NH_3-N/total N	Lactic acid (%)
100-0-0	4.2 a	7.7 c	0.8 d
100-0-5	4.3 a	9.3 bc	1.0 d
100-0-10	4.3 a	12.9 a	1.2 d
95-5-0	4.2 a	11.9 ab	1.1 d
95-5-5	4.3 a	11.3 ab	1.5 b
95-5-10	4.3 a	7.4 c	1.6 b
90-10-0	4.2 a	7.3 c	1.3 b
90-10-5	4.2 a	9.9 bc	1.3 b
90-10-10	4.2 a	9.7 bc	1.8 a
SEM	0.03	0.24	0.1
OF-GC x SG	NS	NS	NS

Differents letters within a column indicates significant differences (Tukey, P ≤ 0.05). *: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001, NS: non significant, SEM: standard error of the mean.

The highest concentration of lactic acid was registered in the treatments whit 10% of ground corn as well as in treatments where SG was added. The values of lactic acid in this study are considered as adequate (Kung and Shaver, 2001) and may guarantee a good fermentation of forage (Schroeder, 2004). Moreover, the concentrations registered in this study were higher than those reported by Apráez-Guerrero *et al*. (2012) in oat forage silages.

CONCLUSIONS

The inclusion of sunflower grain increases the nutritional value of oat silage when oat forage and ground corn are combined; however, the fermentative quality is not improved.

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