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Production of corn and sunflower fodder, and its preference as silage among ewes in Mineral de la Reforma, Hidalgo

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ABSTRACT

Objective: To assess the forage production of corn and corn with sunflower forage, as well as ewes' preference for this forage as silage.

Design/methodology/approach: A completely randomized block design with three replications was used in the field, while a completely randomized design (Tukey $\alpha=0.05$) was preferred for work in laboratory. Sowing was done in spring-summer 2020 under rainfed conditions. The treatments were as follows: 100% corn; 90% corn + 10% sunflower; and 80% corn + 20% sunflower. Forage production was assessed at 126 days of sowing. Once ensiled, forage was assessed again through a bromatological analysis. Silage preference was evaluated for 20 days with 10 pregnant Hampshire × Suffolk ewes with a live weight of 44.8 kg.

Results: The combination of 80% corn + 20% sunflower delivered a higher fresh forage yield ($P<0.001$; 28 t ha^{-1}), a higher percentage of soluble protein ($P<0.01$), and a higher percentage of lignin ($P<0.001$; 4.6%). The ewes preferred the 100% corn silage, since it contained a lower percentage of non-fiber carbohydrates (22.2%), a lower percentage of acid detergent fiber (35.3%), and a lower percentage of neutral detergent fiber (59.4%).

Study Limitations/Implications: Sunflower should be established in soils with low amounts of broadleaf weed seeds, since chemical control cannot be applied to the said weeds.

Findings/Conclusions: A greater amount of forage was produced per surface unit when 80% corn was combined with 20% sunflower. Ewes preferred the 100% corn silage due to its lower percentage of lignin and a higher *in vitro* digestibility of neutral detergent fiber.

Key words: Alternative forage, Nutritional quality of silage, Silage preference.

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INTRODUCTION

Feed for ruminant cattle in production is based on forage crops and grazing forage. However, the use of silages is important to maintain the animals' body condition during the dry season without reducing livestock efficiency (Echavarría, 2007).

The sunflower is native to northern Mexico and the southeastern United States. Its fresh forage yield is approximately 8-12 t ha^{-1} (Fassio *et al.*, 2001). The crude protein (CP) content in the bud, flowering, and physiological maturity stages is 16, 11, and 9%, respectively. Meanwhile, digestibility of its organic matter is 75 (bud), 72 (flowering), and 63% (physiological maturity). In this regard, after assessing 13 sunflower genotypes, Tomich *et al.* (2003) reported yields of 12.1-29.1 t ha^{-1} on a wet basis. Velázquez-Martínez et al. (2018) reported yields of fresh corn forage in the semiarid rainfed conditions of the State of San Luis Potosí: 4.8 t ha^{-1} in Charcas and 28.0 t ha^{-1} in Matehuala. This indicates variability between the types of corn used by local producers under different soil and moisture conditions. Similarly, after assessing several combinations of corn and sunflower (100% corn, 75% corn + 25% sunflower, 50% corn + 50% sunflower, 25% corn + 75% sunflower, and 100% sunflower) in Almoloya de Juárez, Estado de México, Aragadvay-Yungán *et al.* (2015) concluded that sunflower silage could be an alternative to substitute up to 25% of corn silage. Sunflower provides a similar level of protein and energy supply than monoculture corn silage. However, water demand (consumptive use) is different for each crop: 467 mm for corn and 390 mm for sunflower (Villanueva *et al.*, 2001). This is an important factor for places with scarce and badly distributed rainfall.

When describing ewes' selection of forage material, Anderson *et al.* (2010) mention that ewes prefer forage with higher protein contents, low fiber carbohydrate levels, and a high fodder value. Therefore, we must keep in mind that, as plants get older, grass quality decreases due to lignin aggregation (Velázquez-Martínez *et al.*, 2022). The organic matter digestibility of sunflower decreases with physiological maturity, as a consequence of a higher lignin content, as well as of high oil contents, which affect the metabolism of ruminal microbiota (Fassio *et al.*, 2001).

Consequently, the combined cultivation of corn and sunflower in different proportions for silage during the wet season can improve the nutritional quality of silage. Sheep will normally select the silage with the highest percentage of protein, highest digestibility, and lowest lignin levels. Since this phenomenon has not been documented, the objective of our study was to assess different combinations of forage production (100% corn, 90% corn + 10% sunflower, 80% corn + 20% sunflower), to ensile them, to conduct a bromatological analysis in a certified laboratory, and, finally, to determine which of the three silages sheep prefer as feed.

MATERIALS AND METHODS

Study site

The study was conducted at La Pila, Mineral de la Reforma, State of Hidalgo, Mexico, during the 2020 spring-summer agricultural cycle. The site is located at 20° 07' 06.22" N and 98° 40' 29" W, at an altitude of 2,510 m. The climate is temperate semi-arid,

with an average annual temperature of 15 °C and 540 mm of rainfall. The type of soil is Vertisol with a clayey texture (Ramírez-Bautista *et al.*, 2017). We used corn seeds of the Asgrow brand, Faisán variety, which is a three-way cross that flowers 95 days after sowing. The sown sunflower (*Helianthus annuus*) was of the Sunspot variety, which reaches the milk-dough stage at 126 days. The ewes used to select the silage were 18-month-old Suffolk×Hampshire crossbreeds with a 4-month pregnancy and an average live weight of 44.85 kg. The study comprised soil preparation, sowing, first and second weeding, cutting, and silage of forage materials (June-November, 2020), as well as ewe conditioning and the selection of silage by the ewes (December, 2020-January, 2021).

Soil preparation was carried out on May 26, 2020 and comprised a fallowing and two harrowings. Sowing was carried out on June 6, 2020 on soil at field capacity, at a depth of 15 cm, with a manual grain drill and without fertilization. Forage materials proportions (treatments) were 100% corn, 90% corn + 10% sunflower, and 80% corn + 20% sunflower, all of which were sown in three complete randomized blocks with three replications. Following Escalante-Estrada *et al.* (2008), we sowed 75,000 plants ha^{-1}. When combining corn and sunflower, seeds were mixed according to each company's information on purity and viability. Subsequently, seeds were weighed on a Truper® scale No. 15161 (5.0 kg; México).

The experimental unit consisted of two 6-m long furrows separated by 0.80 m. The forage was cut 10 cm above the soil surface and weighed on a Torino® dial hanging scale (Morelia, Michoacán, Mexico). Forage materials were harvested at 126 days, as indicated by Aragadvay-Yungán *et al.* (2015). The dry matter sample was determined by weighing all fresh forage in each experimental unit, and then weighing 25% of the said forage, mincing it, and laying it out on paper in a ventilated greenhouse for 15 days. Afterwards, each treatment's materials were put in previously labelled paper bags and arranged in a Ciderta® air forced stove (Huevla, Spain) at 55 °C during 5 hours, and then they were weighed. To ensile the forage, we minced it manually (<1 inch), placed it inside 100-L plastic barrels in duplicate, compacted it gradually, and hermetically sealed the barrels. After 45 days, the barrels were opened and the dry matter was determined. When three replications of the dry matter sample reached a weight of 2.0 kg in on a Truper© digital scale No. 15161, the silages were placed in a greenhouse environment with air flow for two weeks. Afterwards, they remained in an air forced stove at 55 °C for 5 h and were weighed. To conduct the analyses, 0.5-kg samples were taken per treatment on a dry basis in duplicate and sent to the Agro Lab de México S.A. de C.V. certified laboratory, in Gómez Palacio, Durango, Mexico. The following data were determined in the said lab: crude protein percentage (CP; %), soluble protein (%), acid detergent fiber (ADF; %), neutral detergent fiber (NDF; %), non-fiber carbohydrates (NFC; %), fat (%), total digestible nutrients (TDN; %), organic matter digestibility at 30 h (%), *in vitro* dry matter digestibility (%), and *in vitro* NDF digestibility (%). In addition, the following data were determined in Mcal kg^{-1}: net energy for lactation (NE_l), net energy for maintenance (NE_m), net energy gain (NE_g), and metabolic energy (ME). With these results, we were able to start the ewes' silage selection test.

Animal conditioning and experimental management

Before the silage selection process, ewes were dewormed with 0.1% subcutaneous ivermectin at doses of 20 μL kg^{-1} body weight and oral albendazole at doses of 200 μL kg^{-1} body weight and revaccinated with subcutaneous one-shot Biobac 7-way bacterin at doses of 20 μL kg^{-1} body weight. Afterwards, ewes were placed for their adaptation in individual shaded corrals (1.5×1.7 m) for nine days from 13:00 to 17:00 h. They were provided rye grass hay and water *ad libitum*. The ewes' silage selection was evaluated for 20 days. Ewes remained together from 08:00 to 12:00 h and were offered 700 g animal^{-1} rye grass hay and water *ad libitum*. The selection of the three silages took place between 13:00 and 17:00 h in the individual corrals with water *ad libitum*. In each corral, we placed a trough with three separate compartments holding 510 g of each silage: 1) corn silage; 2) 90% corn + 10% sunflower silage; and 3) 80% corn + 20% sunflower silage. After 17:00 h, all animals remained together for the night.

The assessed variables were: production of fresh forage and dry matter (t ha^{-1}); bromatological analysis in the laboratory; and which of the three silages the ewes preferred (g animal^{-1}). In addition, ewes were weighed before and after the experiment with a 200-kg Torino© hanging crane scale (Mexico) with a 0.5 kg interval.

Data analysis

Data were subjected to an analysis of variance using the statistical software SAS/STAT (2010) and means were compared using Tukey's test (α=0.05), before conducting Bartlett's test for homogeneity of variance. The forage production model was as follows:

$$Y_{ij}=\mu Treat_i+Block_j+e_{ij}, \quad (1)$$

where Y_{ij}=response variable in treatment i, replication j; μ=overall mean; $Treat_i$=effect of treatment i, where i=1, 2, and 3; $Block_j$=effect of block j; e_{ij}=random error.

The model used to analyze the consumption preference data was as follows:

$$Y_{ijk}=\mu+Sup_i+Day_j+(Sup_i\times Day_j)+e_{ijk} \quad (2)$$

where Y_{ijk}=observed response in the sampling time in the *j-th* subsample, *i-th* sunflower inclusion level, in the *k-th* replication; μ=overall media; Sup_i=effect of the type of supplement i, where i=1, 2, and 3; Day_j=effect of the sample on time j, where j=1... 20; $Sup_i\times Day_j$=effect of the interaction between the *i-th* type of supplement and the *j-th* sampling day; e_{ijk}=experimental error associated with all observations (Y_{ijk}).

RESULTS AND DISCUSSION

We observed a difference between the fresh forage yield (P<0.001) and dry forage (P<0.01; Table 1): 80% corn + 20% sunflower was 1.15 times higher than corn monoculture, contrary to the findings of Warren (1980), who observed a higher amount of dry matter in corn monoculture (11.2 *v.* 9.3 t ha^{-1}). A comparison between the production of fresh

Table 1. Production in rainfed conditions of fresh corn forage and dry corn fodder, and corn + sunflower fodder in Mineral de la Reforma, State of Hidalgo, Mexico.

Proportion of the seeds sowed	FM (t ha^{-1})	DM (t ha^{-1})
Corn 100%	22.4 c †	7.0 b
Corn 90% + sunflower 10%	24.8 b	7.4 ab
Corn 80% + sunflower 20%	28.0 a	8.0 a
Average	25.1	7.4
Significancy	***	*
SEM	0.32	0.15

† Different lower-case letters in the same column are statistically different averages; ***P<0.001, *P<0.05. FM=Fresh matter, DM=Dry matter. SEM=Standard error of the mean.

corn forage obtained in this study and the results of Velázquez-Martínez *et al.* (2018) for Charcas (4.8 t ha^{-1}) and Matehuala (28 t ha^{-1}) shows that production in Mineral de la Reforma, Hidalgo, is within the range of corns cultivated under rainfed conditions. A higher proportion of sunflower resulted in a higher forage yield (P<0.01). However, growing sunflower is difficult, since its development in soils with a history of weed seedbanks will be lower, because selective herbicides for broadleaf weeds cannot be applied.

The bromatological analysis of silages based on corn monoculture (90% corn + 10% sunflower, and 80% corn + 20% sunflower) did not show any differences (P>0.05) regarding CP and total digestible nutrients (TDN) (Table 2). However, soluble protein was higher in 90% corn + 10% sunflower (P<0.01), which matched a higher score in the production of volatile fatty acids. We can therefore assume that microorganisms make better use of forage protein for multiplication, which results in a higher production of metabolic protein and volatile fatty acids (Velázquez-Martínez *et al.*, 2022). In this regard, Okoruwa and Igene (2014) mention that a higher digestibility of neuter detergent fiber (NDF) in rumen results in a higher production of volatile fatty acids in the following order: acetate, propionate, and butyrate. This phenomenon was observed in the monoculture silage (P<0.01). The metabolic energy of forage depends on the digestibility and concentration of protein, fat, fiber and non-fiber carbohydrates, as well as on carbohydrate type and digestibility (Núñez *et al.*, 2014). All these elements affect the ruminants' consumption of dry matter.

We observed differences (P<0.001; Figure 1) when testing which silages ewes preferred to consume; however, there were no differences for time (P=0.0784) or interaction (P=0.8781). The average silage consumption was: 355 g animal^{-1} d^{-1} for 100% corn; 237 g animal^{-1} d^{-1} for 90% corn + 10% sunflower; and 235 g animal^{-1} d^{-1} for 80% corn + 20% sunflower. Corn monoculture was 1.5 times higher than both combinations. The means comparison test showed that ewes preferred the monoculture silage over the corn and sunflower silage (P<0.01) and that no differences were observed between silages with sunflower (P>0.05; Figure 1). This could be explained by the lab results, which show that the corn silage contained less lignin (P<0.001; Table 2). In addition, the content of non-fiber carbohydrates was higher in the corn silage (P<0.01), another reason for ewes to like it better. This phenomenon was recorded by Anderson *et al.* (2010), who mention that

Table 2. Chemical composition of three silages produced under rainfed conditions in Mineral de la Reforma, Hidalgo, Mexico, and used for selection by ewes.

Variable	Corn 100%	Corn 90% - sunflower 10%	Corn 80% - sunflower 20%	Significancy	SEM
Crude protein (%)	10.4	10.2	10	NS	0.07
Soluble protein (%)	59.0 c †	72.5 a	66.0 b	0.01	0.86
ADF (%)	35.4 b	35.9 a	35.8 a	0.01	0.043
NDF (%)	59.3 b	61.1a	61.9 a	0.01	0.18
Lignin (%)	3.2 c	3.6 b	4.6 a	0.001	0.043
DIV 30 h (%)	80.5 a	77.5 b	78.1ab	0.05	0.41
DIV NDF 30 h (%)	67.3 a	65.2 b	64.1b	0.01	0.17
NFC (%)	22.3 a	20.5 c	21.6 b	0.01	0.05
Fat (%)	2.9 a	2.3 b	2.2 b	0.01	0.04
TDN (%)	58.9	59.3	57.5	NS	0.33
NE_l (Mcal kg^{-1})	1.19 a	1.16 ab	1.12 b	0.05	0.007
NE_m (Mcal kg^{-1})	1.18 a	1.17 a	1.12 b	0.01	0.005
NE_g (Mcal kg^{-1})	0.62 a	0.61a	0.55 b	0.01	0.004
ME (Mcal kg^{-1})	2.38 a	2.29 b	2.22 c	0.01	0.01
VFA value	6.27 b	7.16 a	5.48 c	0.001	0.007

† Means with the same letter in the same line are not statistically different (Tukey α=0.05). SEM=Standard error of the mean. NS=Not significant (P>0.05). ADF=Acid detergent fiber. NDF=Neutral detergent fiber. IVD=*In vitro* digestibility. NFC=Non-fiber carbohydrates. NE_l=Net energy for lactation. NE_m=Net energy for maintenance. NE_g=Net energy for gain. ME=Metabolic energy. VFA=Volatile fatty acids.

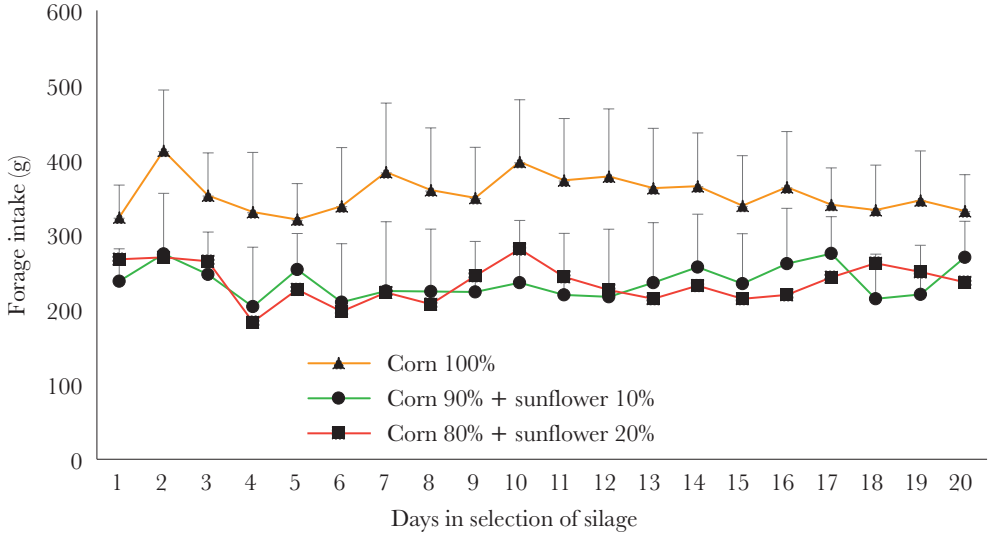

Figure 1. Ewes' silage consumption preference in Mineral de la Reforma, Hidalgo, Mexico.

ewes select their diet based on the crude protein, digestible and non-digestible fiber, and lower pubescence of forage materials; therefore, silages with sunflower are less likely to be preferred. The ewes' final average weight after 20 days of silage selection was 49.77 kg. The daily weight gain was 0.258 g.

CONCLUSIONS

When more forage per surface unit must be produced, the best combination for the site under rainfed conditions is 80% corn + 20% sunflower. However, ewes preferred the 100% corn silage as a result of its lower percentage of neutral detergent fiber and its lower lignin content, which improves digestibility.

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