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Corresponding authors:
Einar Vargas-Bello-Pérez
Email: e.vargasbelloperez@reading.ac.uk;
Manuel Gonzalez Ronquillo;
Email: mrg@uaemex.mx

Productive performance and milk composition of dairy ewes supplemented with corn silage (*Zea mays* L.), sunflower (*Helianthus annuus*) silage and their mixture

Manuel Gonzalez-Ronquillo[1], Navid Ghavipanje[2], Lizbeth E. Robles-Jimenez[1,3], Eduardo Cardoso-Gutierrez[1], Edgar Aranda-Aguirre[1], Augusto Lizarazo[4], Ricardo A. Garcia Herrera[3], Octavio A. Castelán Ortega[1] and Einar Vargas-Bello-Pérez[5,6]

[1]Departamento de Nutricion Animal, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autonoma del Estado de Mexico, Instituto Literario 100 Ote, Toluca, State of Mexico 50000, Mexico; [2]Department of Animal Science, Faculty of Agriculture, University of Birjand, Birjand 97175-331, Iran; [3]División Académica de Ciencias Agropecuarias, Universidad Juárez Autónoma de Tabasco, Carretera Villahermosa-Teapa, km 25, R/A. La Huasteca 2ª Sección, CP 86280, Villahermosa, Tabasco, Mexico; [4]Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autonoma del Mexico, Ciudad de Mexico, Mexico; [5]Department of Animal Sciences, School of Agriculture, Policy and Development, University of Reading, P.O. Box 237, Earley Gate, Reading RG6 6EU, UK and [6]Facultad de Zootecnia y Ecología, Universidad Autónoma de Chihuahua, Periférico R. Aldama Km 1, 31031 Chihuahua, Mexico

Abstract

The work reported in the Research Communication investigated *in vitro* rumen gas kinetics and fermentation profile as well as *in vivo* performance of lactating ewes fed corn silage (CS), sunflower silage (SFS) and their 50 : 50 mixture (CS-SFS). For the *in vivo* experiment, nine early-lactation Suffolk × Texel ewes were grouped in a replicated 3 × 3 Latin square design of three 21-d periods. Treatments were based on *ad libitum* CS, SFS, and CS-SFS supplemented with concentrate at 48 g/kg $LW^{0.75}$. *In vitro* results showed that the CS had the highest dry matter degraded substrate and microbial crude protein production followed by CS-SFS. The *in vivo* data showed that animals fed on CS had higher digestibility of dry matter and organic matter than CS-SFS, while SFS were intermediate. Nitrogen (N) intake, fecal N excretion, and urine N excretion were similar between groups, however, milk N excretion was lower in SFS than CS. Milk yield was higher for CS and CS-SFS than SFS group, however, SFS-fed ewes had higher milk fat content than either CS or CS-SFS (all differences reported here were significant, $P < 0.05$ or better). Overall, CS-SFS could be used as dietary roughage for dairy ewes without deleterious effects on nutrient intake, N-balance and milk yield whilst potentially offering a more sustainable alternative to CS.

Silage is a common form of roughage that allows the preservation of nutritional characteristics for prolonged periods (Jacobsen *et al*., 2013; Cardoso-Gutiérrez *et al*., 2020). In the Americas, corn silage (CS) is the most prevalent preserved roughage in dairy ruminant diets, however, its production is limited in some parts of the world due to land degradation and water scarcity (Jacobsen *et al*., 2013). Therefore, alternative roughage resources with high crude protein (CP) content, digestibility, yield and reduced water requirements need to be explored for ruminant feeding (Wirsenius *et al*., 2010; Jacobsen *et al*., 2013). Sunflower (*Helianthus annuus*) includes 67 annual and perennial species that are extensively used for seed and oil production throughout the world (Tan *et al*., 2014; Aragadvay-Yungán *et al*., 2015). Sunflower is drought-tolerant and cold-resistant due to its deep root system (Tan *et al*., 2014). It requires less water than maize and, as roughage, serves as a valuable source of protein and lipids (Demirel *et al*., 2009). It has been shown that sunflower silage (SFS) has an 80% similar feeding value to CS with higher crude protein and fat content (Tan *et al*., 2014). Hence, SFS is a viable alternative to CS as a feed source for ruminants, particularly in regions with limited water resources (Jacobsen *et al*., 2013; Aragadvay-Yungán *et al*., 2015). However, its ensiling may be difficult due to low dry matter (DM) content and a medium CP content that does not promote rapid lowering of pH (Demirel *et al*., 2009; Tan *et al*., 2014). With further development, SFS may become an alternative roughage for sheep, helping to mitigate climate change issues due to its lower water requirement (Wirsenius *et al*., 2010). To our knowledge, no studies have investigated the effects of feeding CS, SFS and their mixture with concurrent use of *in vitro* and *in vivo* approaches. Therefore, we aimed to determine chemical composition, nutrient digestibility, nitrogen-balance and milk yield of dairy ewes fed on CS, SFS and their 50:50 mixture (CS-SFS).

Materials and methods

The research was carried out at the Animal Science farm of the School of Veterinary Medicine and Animal Science of the Universidad Autónoma del Estado de México, under the approved ID project UAEMex 4974/2020.

In vitro rumen gas kinetics and fermentation profile were assessed using three fistulated ewes and 96 h incubation of samples. The experimental procedures and data analysis are detailed in the online Supplementary File.

For the *in vivo* experiment, nine Suffolk × Texel dairy ewes (45 ± 6 (SD) days in milk, 79.9 ± 10 kg body weight, 0.55 ± 0.14 kg/d milk yield) were grouped in a replicated 3 × 3 Latin square design ($n = 3$), that included three 21-d periods of which 14 d were used for diet adaptation and the last 7 d for sample collection. The three dietary treatments consisted of forage (CS, SFS or their 50:50 mixture, CS-SFS) and concentrate (30% corn grain and 70% soybean meal) supplemented with vitamins and minerals (Multitec of Malta®; Celaya; Mexico). Diets with 50:50 forage to concentrate ratio were formulated to be isocaloric and meet NRC (2007) requirements of dairy ewes (online Supplementary Table S1). Forage and concentrates were manually mixed and offered twice per day (0800 h and 1600 h), with free access to water. Animals were kept in a roofed pen with individual metabolic cages (1.0 × 1.2 × 1.2 m) with slatted floor. Individual milk samples (100 ml) were collected at 16 : 00 h from 2 consecutive milkings and analyzed for fat, protein, lactose, total solids (TS) and non-fat solid (SNF) on an infrared milk analyzer (Milko Scan FT 200, Foss Electric, Hillerod, Denmark).

Statistical analysis

Data were analyzed in SAS 9.2 (SAS/STAT, SAS Institute Inc., Cary, NC) using a completely Latin square design, with the factors being the silage supplementation ($n = 3$) with the following equation:

$$Y_{ij} = \mu + A_i + P_j + T_k + e_{ijkl}$$

where Y_{ij} is the dependent variable, μ is the general average, A_i is the animal, P_j is the period, T_k is the silage supplementation treatment and e_{ijkl} the error term. Least square means (LSM) separation was performed using the PDIFF statement by Tukey's test and presented as LSM ± SEM. Significance was declared at $P \le 0.05$.

Results

In this research communication, we focus on milk production and milk composition, while providing detailed information on *in vitro* gas kinetics and *in vivo* digestibility in the online Supplementary Material accompanying the paper. Briefly, *in vitro* trial showed that the highest total gas production, dry matter degraded substrate and microbial crude protein production (all significant, $P = 0.001$) was for CS, followed by CS-SFS (online Supplementary Table S2). Total intake of dry matter and organic matter were not altered by diets ($P > 0.05$, online Supplementary Table S3). However, the N balance was higher for SFS compared with both CS and CS-SFS ($P < 0.05$, online Supplementary Table S4). The highest milk yield was observed in CS group, followed by CS-SFS ($P < 0.05$, Table 1). However, fat corrected milk and protein and fat corrected milk were not affected by diet ($P > 0.05$). Similarly, feed efficiency estimations (namely energy corrected and fat and protein corrected milk yields in relation to dry matter intake) were not altered by diets ($P > 0.05$), but the highest ($P < 0.05$) milk yield:DMI was observed in CS-fed ewes. In terms of milk components, the concentration (g/100 g) of fat, lactose, total solids and protein was higher in CS supplemented ewes followed by CS-SFS ($P < 0.05$ or better). Likewise, except for fat yield (which was not altered), all milk component yields were higher in both CS and CS-SFS than SFS.

Table 1. Milk yield and components in dairy ewes fed diets based on corn silage (CS), sunflower silage (SF) and their mixture (CS-SFS)

	Diets				
Item	CS	SFS	CS-SFS	SEM	*P* value
Yield					
Milk yield, kg/d	0.74^{a}	0.42^{b}	0.63^{ab}	0.079	0.0242
FCM (6.5%), kg/d	0.69	0.49	0.62	0.076	0.1619
FPCM (6.5%), kg/d	0.67	0.46	0.60	0.072	0.1176
Feed efficiency					
Milk yield:DMI	0.29^{a}	0.16^{b}	0.27^{ab}	0.037	0.0445
ECM:DMI	0.28	0.19	0.26	0.034	0.1905
FPCM:DMI	0.27	0.18	0.25	0.032	0.1603
Milk component concentrations, g/100 g					
Fat	6.02^{b}	8.15^{a}	6.41^{b}	0.427	0.0040
Lactose	4.43^{a}	4.09^{b}	4.26^{ab}	0.080	0.0237
Total solids	9.89^{a}	9.14^{b}	9.51^{ab}	0.177	0.0216
Protein	4.69^{a}	4.33^{b}	4.54^{ab}	0.086	0.0272
Milk component yields, g/d					
Fat	43.21	34.30	40.95	4.994	0.4560
Lactose	32.49^{a}	16.97^{b}	26.54^{ab}	3.167	0.0071
Total solids	72.54^{a}	37.87^{b}	59.22^{ab}	7.079	0.0072
Protein	34.35^{a}	17.95^{b}	28.21^{ab}	3.336	0.0069

FCM, fat corrected milk; FPCM, fat and protein corrected milk; ECM, energy corrected milk; DMI, dry matter intake; SEM, pooled standard error of the mean.
Values are least-square means.
Within rows, different superscript letters indicate difference between diets ($P \le 0.05$).

Discussion

Global water scarcity, climate change, and food-feed-fuel competition constrain crop production in some regions, emphasizing the importance of efficient roughage use (Wirsenius *et al.*, 2010; Jacobsen *et al.*, 2013). SFS offers a valuable feeding source, however, there is still a lack of information on its usage as ruminant feed.

We showed that dietary inclusion of SFS was associated with lower *in vitro* degraded dry matter and microbial crude protein production which agrees with previous studies (Aragadvay-Yungán *et al.*, 2015) and is probably mainly related to the lower metabolizable energy and higher non-degradable fiber content of SFS. The lower *in vivo* digestibilities of dry matter and organic matter in

SFS-fed animals may also be related to the higher fiber content of SFS that is consistent with previous data in dairy cows (Demirel *et al*., 2009). The inclusion of SFS in the diet of lactating ewes resulted in lower milk production as well as reduced lactose, total solids and protein contents. However, milk fat percentage was enhanced with SFS feeding. Even though milk production decreased in ewes fed SFS containing diets, fat and fat-and-protein corrected milk yields were not affected. This suggested that the inclusion of SFS led to improved milk fat content compared to CS. Higher milk fat in SFS fed ewes may be explained by the higher fiber content of the diet. In accordance with our results, Sainz-Ramírez *et al.* (2021) reported that fat corrected milk (4%) was similar in dairy cows fed CS and SFS. Daily yield of milk components was different between diets and feeding SFS resulted in a significant reduction in daily production of protein, lactose and total solids. Lower daily lactose production can be explained by a reduction in diet fermentation (Ivan *et al*., 2004). Milk protein production was closely linked to dietary CP, rumen fermentable carbohydrates and rumen microbial protein synthesis. Moreover, lower milk production is a factor limiting daily milk protein yield (Cardoso-Gutiérrez *et al*., 2020). The higher milk protein of CS-SFS than SFS group may be related to the fact that this treatment may have been able to provoke rumen defaunation of ciliated protozoa that led to increases in rumen microbial synthesis of protein (Ivan *et al*., 2004; Cardoso-Gutiérrez *et al*., 2020).

In conclusion, dietary inclusion of SFS for lactating dairy ewes decreased milk yield, however, fat corrected and protein-and-fat corrected milk yields were not affected, and nitrogen balance was enhanced. In addition, milk fat percentage was enhanced with SFS. Overall, CS-SFS could be used as dietary roughage for dairy ewes as an alternative to the use of CS. Further studies should examine rumen function, milk fatty acid profiles and dairy product quality.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0022029924000293.

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References

Aragadvay-Yungán RG, Rayas Amor AA, Heredia-Nava D, Estrada-Flores JG, Martínez-Castañeda FE and Arriaga-Jordán CM (2015) *In vitro* evaluation of sunflower (*Helianthus annuus* L.) silage alone or combined with maize silage. *Revista Mexicana de Ciencias Pecuarias* **6**, 315–327.

Cardoso-Gutiérrez E, Narváez-López AC, Robles-Jiménez LE, Morales Osorio A, Gutierrez-Martinez MDG, Leskinen H and González-Ronquillo M (2020) Production performance, nutrient digestibility, and milk composition of dairy ewes supplemented with crushed sunflower seeds and sunflower seed silage in corn silage-based diets. *Animals* **10**, 2354.

Demirel M, Bolat D, Çelik S, Bakýcý Y and Eratak S (2009). Determination of fermentation and digestibility characteristics of corn, sunflower and combination of corn and sunflower silages. *Journal of Animal and Veterinary Advances* **7**, 707–711.

Ivan M, Mir PS, Mir Z, Entz T, He ML and McAllister TA (2004) Effects of dietary sunflower seeds on rumen protozoa and growth of lambs. *British Journal of Nutrition* **92**, 303–310.

Jacobsen SE, Sørensen M, Pedersen SM and Weiner J (2013) Feeding the world: genetically modified crops versus agricultural biodiversity. *Agronomy for Sustainable Development* **33**, 651–662.

National Research Council (2007) *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids and New World Camelids*. Washington, DC: National Academy Press.

Sainz-Ramírez A, Velarde-Guillén J, Estrada-Flores JG and Arriaga-Jordán CM (2021). Productive, economic, and environmental effects of sunflower (*Helianthus annuus*) silage for dairy cows in small-scale systems in central Mexico. *Tropical Animal Health and Production* **53**, 1–11.

Tan M, Yolcu H and Dumlu Gul Z (2014) Nutritive value of sunflower silages ensiled with corn or alfalfa at different rate. *Journal of Agricultural Sciences* **21**, 184–191.

Wirsenius S, Azar C and Berndes G (2010) How much land is needed for global food production under scenarios of dietary changes and livestock productivity increases in 2030? *Agriculture Systems* **103**, 621–638.