

The potential of sunflower (*Helianthus annuus*) residues silage as a forage source in Mohabadi dairy goats

Amir Gholami-Yangije, Rasoul Pirmohammadi*, Hamed Khalilvandi-Behroozyar

Department of Animal Sciences, Faculty of Agriculture, Urmia University, Urmia, Iran.

| Article Info | Abstract |
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| <p>Article history:</p> <p>Received: 26 August 2017 Accepted: 21 February 2018 Available online: 15 March 2019</p> <p>Key words:</p> <p>By-products Forage Processing Silage Sunflower</p> | <p>This study was conducted to determine the chemical composition and nutritive value of sunflower residues silage (SRS) and effects of its substitution with alfalfa hay and corn silage on lactation performance, feed intake, nutrient digestibility and some blood parameters of Mohabadi dairy goats. Four experimental diets were formulated to gradually replace alfalfa hay and corn silage with SRS as follows: Control (no inclusion of SRS, group 1) and groups 2 to 4, representing 15, 30 and 45.00% replacement of common forages in the diet with SRS, respectively. Sixteen multiparous dairy goats weighing 60.00 ± 3.00 were divided into two 4×4 latin square design. Ensiling was being able to increase crude protein content, reduce neutral detergent fiber and increase acid detergent lignin in sunflower residues. Daily dry matter (DM) intake and DM and organic matter (OM) digestibility decreased with increasing levels of SRS in the diet. The highest and the lowest digestibility coefficients belonged to 30 and 45.00% embedment levels, respectively. Milk yield decreased with increasing levels of SRS and differences were statistically significant compared to the highest substitution level. Milk composition was similar among diets, but daily production of milk decreased in higher substitution levels. Statistically significant differences were found in serum low-density lipoproteins (LDL) concentrations between treatments and LDL levels decreased as dietary levels of SRS increased. According to these results, SRS is an acceptable feed for dairy goats and common dietary forages can be replaced up to 30.00% with SRS without negative effects on milk yield and composition.</p> <p style="text-align: right;">© 2019 Urmia University. All rights reserved.</p> |

قابلیت بقایای سیلوشده آفتابگردان (*Helianthus annuus*) به عنوان یک منبع علوفه در بز شیری مهابادی

چکیده

این مطالعه به منظور تعیین ترکیب شیمیایی و ارزش تغذیه ای بقایای سیلوشده آفتابگردان و آثار جایگزینی آن با یونجه خشک و ذرت سیلوشده بر عملکرد تولید شیر، میزان خوراک مصرفی، گوارش-پذیری مواد مغذی و برخی فراسنجه‌های خونی بزهای شیری مهابادی بود. ۴ جیره آزمایشی جهت جایگزینی تدریجی یونجه خشک و ذرت سیلوشده با بقایای سیلوشده آفتابگردان تهیه شد: جیره شاهد (فاقد بقایای سیلوشده آفتابگردان، گروه ۱) و گروه‌های ۲ تا ۴ به ترتیب شامل جایگزینی ۱۵/۰۰، ۳۰/۰۰ و ۴۵/۰۰ درصد از منابع علوفه معمول جیره با بقایای سیلوشده آفتابگردان. شانزده رأس بز شیری چند بار زایش کرده با میانگین وزنی $60/00 \pm 3/00$ کیلوگرم در دو مربع لاتین مستقل 4×4 تقسیم شدند. سیلونمودن بقایای آفتابگردان سبب افزایش میزان پروتئین خام، کاهش الیاف نامحلول در شونده خشی و افزایش لیگنین نامحلول در شونده اسیدی شد. میزان ماده خشک مصرفی روزانه و گوارش‌پذیری ماده خشک و ماده آلی با افزایش سطوح بقایای سیلوشده آفتابگردان در جیره کاهش یافت. بیشترین کمترین ضرایب گوارش‌پذیری به ترتیب مربوط به سطوح جایگزینی ۳۰/۰۰ و ۴۵/۰۰ درصد بود. تولید شیر با افزایش سطوح بقایای سیلوشده آفتابگردان کاهش یافت و تفاوت‌ها نسبت به بالاترین سطح جایگزینی از نظر آماری معنی‌دار بودند. ترکیب شیر بین جیره‌ها مشابه بود، ولی تولید روزانه ترکیبات شیر در سطوح جایگزینی بالاتر کاهش یافت. تفاوت‌های آماری معنی‌داری در غلظت‌های لیپوپروتئین با چگالی کم (LDL) سرم بین تیمارها یافت شد و با افزایش سطوح بقایای سیلوشده آفتابگردان، سطح LDL کاهش یافت. بر اساس نتایج این آزمایش، بقایای سیلوشده آفتابگردان خوراکی قابل قبول برای بزهای شیری می‌باشد و می‌تواند بدون آثار منفی بر تولید و ترکیب شیر، تا ۳۰ درصد جایگزین علوفه‌های معمول جیره گردد.

واژه‌های کلیدی: آفتابگردان، علوفه، علوفه سیلوشده، فرآورده‌های جانبی، فرآوری

*Correspondence:

Rasoul Pirmohammadi. PhD
Department of Animal Sciences, Faculty of Agriculture, Urmia University, Urmia, Iran
E-mail: r.pirmohammadi@urmia.ac.ir



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Introduction

Ruminants ability to efficient digestion of agricultural by-products made them important animals in the human food supply chain without pressurized land and water sources.^{1,2} Sunflower (*Helianthus annuus*) includes 67 annual and perennial species² and is extensively used for seed and oil production throughout the world. In Iran, sunflower seed production was reached to 3 million metric tons in 2005 and continues to rise each year. Accordingly, by-products of the sunflower seed production increased.³ However, there are very limited data about dietary inclusion of sunflower residues in ruminant nutrition. In addition to data shortage, available data are not about a uniform product and different parts of the plant or in some cases the whole plant residues were examined. Lehmkuhler and Kerley have declared that the sunflower head is palatable and highly digestible.⁴ Lardy and Anderson have studied nutritive value of different sunflower parts and have revealed that the head contains the supreme of available nutrients, followed by the top, middle and bottom thirds of the stalks.⁵

Analysis of nutrient content (neutral detergent fiber (NDF), crude protein (CP) and phosphorous contents of 380.00 ± 73.00 , 93.00 ± 26.00 and 2.20 ± 0.70 g kg⁻¹ dry matter (DM), respectively) and *in vitro* DM digestibility (IVDMD; $71.50 \pm 6.20\%$) of sunflower-cob residues, ranked it as an acceptable feed for dry gestating beef cows.⁶ In the case of the whole plant residues, researchers have reported that sunflower silage can be 80.00 to 85.00% as valuable as corn silage, but higher dietary inclusion rates without processing may turn to a problem, especially with high-oil varieties.^{7,8}

Ammoniation of sunflower-cob residues was reported to increase the CP content, but was unable to change IVDMD and NDF concentration.⁶ Amini-Jabalkandi *et al.* have investigated the effects of substitution of alfalfa hay with sunflower residue silage (SRS) on fattening efficiency of male buffaloes and have indicated that 50.00% of substitution can be considered as an optimal point without negative effects on performance.⁹

To our knowledge, data are not available about the nutritive value of sunflower residues in lactating animals. Accordingly, the main objective of the present study was to determine the potential ability of SRS to replace alfalfa hay and corn silage in the diet of lactating dairy goats.

Materials and Methods

The animals used herein were cared in accordance with the practices outlined in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (ethic No. UU-15-2650).¹⁰ Goats were fed in individual metabolic enclosures within a well-ventilated stall with free access to water and licking salt blocks.

Animals were removed from individual barns and walked for at least 2 hr a day during milking time.

Sunflower residue samples. Samples were taken from sunflower farms in Urmia, Iran (44.58°E and 37.34°N). Sunflowers were sown in late April 2010 (fertilized with nitrogen and potassium) and harvested in September 2010. At least 30 representative samples (10.00 kg of each) were obtained and cut into 30 to 50 mm length particles and sub-samples were used for chemical analysis after milling through a 1 mm sieve (Wiley mill; Thomas Scientific, Swedesboro, USA). Same materials were used for ensiling and animal feeding trials.

Preparation of SRS. Sunflower heads and stalks were chopped to 20 to 30 mm particles, thoroughly mixed with dried whey and urea (0.005 weights of ensiled materials DM) and ensiled separately or with 60:40 ratios of heads to stalks in a ground silo for 180 days. Silages made with separate parts of the sunflower were used for chemical analysis and to compare the effects of ensiling on nutrient composition of different plant parts. However, SRS made with 60:40 ratios of heads to stalks was included in the experimental rations, it was opened gradually for inclusion in the ration, checked for odor and mold during feeding trial and weekly sampled for chemical analysis.

Chemical laboratory analysis. All chemical analyses were carried out in triplicates and were similar for samples of unprocessed residues, ensiled residues, total mixed rations and feces. Dry matter and ash were determined by drying the samples at 105°C overnight and igniting them in a muffle furnace according to AOAC method 942.05, respectively.¹¹ The ether extract content was determined by BUCHI automated apparatus (Buchi Labortechnik AG, Flawil, Switzerland).¹¹ The total nitrogen (N) content was measured by the Kjeldahl method (Behr Labor-Technik GmbH Dusseldorf, Germany) and CP was calculated as $\text{N} \times 6.25$.¹¹

Contents of NDF,¹² acid detergent fiber (ADF)¹² and acid detergent lignin (ADL) were determined using an automated Ankom Fiber apparatus (Ankom200, ANKOM Technology, Macedon USA).¹¹

In vivo feeding trial. Experimental diets were formulated according to nutrient requirement tables¹³ (forage to concentrate of 81:19) with similar energy, nitrogen, NDF, ADF, calcium and phosphorous levels. Experimental diets were designed to gradually replace alfalfa hay and corn silage with SRS including group 1 as control and groups 2 to 4 representing 15.00, 30.00 and 45.00% replacement, respectively (Table 1).

Sixteen multiparous lactating dairy goats with body weight (BW) of 60.00 ± 3.00 kg and 30 days in milk were divided into four groups of similar BW in a 4×4 balanced change-over design. Each experimental period lasted 14 days for adaptation and seven days for sample collection.

Total mixed rations were prepared daily and provided *ad libitum* in two equal meals (800 and 1600). Goats were milked twice a day and milk samples were already taken from each of milking, mixed accordingly to make a daily sample and analyzed for milk fat, protein, lactose and total solids with automatic apparatus (S50; FOSS, Hilleroed, Denmark).

Dry matter intake (DMI) and total fecal excretion of the goats were recorded daily and feed and fecal sub-samples were withdrawn at regular intervals (every 8 hr) and stored at -20°C until laboratory analysis. Nutrient intake was corrected with the nutrient contents of the ort. Animals were weighted on the last day of each period after morning milking and just before feeding. Blood samples were obtained through a jugular vein using evacuated tubes, 3 hr after morning meal on the last day of each sampling period. Blood samples were centrifuged at 3000 rpm (Universal 320R, Andreas Hettich GmbH & Co. KG., Tuttlingen, Germany) for 15 min at 25°C and the resulting serum was kept in -20°C until analysis. Sodium and potassium concentrations were determined using flame photometer (PFP7; Jenway, Staffordshire, UK), while triacylglycerol, high-density lipoprotein, low-density lipoprotein (LDL), very low-density lipoprotein, cholesterol, and glucose contents were determined spectrophotometrically (S2100; United Products & Instruments, Inc. Dayton, USA) using commercial kits (Pars Azmoon Co., Tehran, Iran).

Calculations and statistical analysis. Comparisons of least significant means for chemical composition data were carried out using GLM procedure of SAS (version 9.1; SAS Institute, Cary, USA) using a complete random design (model 1). Least square means were compared for significant differences with TDIF after Tukey adjustment. Significance was declared at $p \leq 0.05$, trends were declared at $p < 0.10$ and $p > 0.05$ using Tukey multiple comparison test.

$$Y_i = \mu + T_i + \varepsilon_i \quad [\text{model 1}]$$

where, μ is the overall mean, T_i is the fixed effect of sunflower residue preparation type (ensiled versus untreated) and ε_i is the residual errors.

Data concerning DMI, milk yield and composition, digestibility coefficients and blood parameters were analyzed by the MIXED procedure of SAS 9.1 with repeated balanced change over design with repeated measurements (model 2). The variance-covariance structure was set as a compound symmetry. Least square means were compared for significant differences with PDIF after Tukey adjustment. All statements of significance were based on the probability level of 0.05. Also, a tendency was detected in $p < 0.10$. Data were shown as least square means with corresponding standard errors.

$$y_{ij(k)lm} = \mu + SQ_m + ROW(SQ)_{im} + COL(SQ)_{jm} + \tau(k) + t_l + P_n + \varepsilon_{ij(k)lm} \\ i, j, k, l = 1, \dots, r; m = 1, \dots, b \quad [\text{model 2}]$$

where, $y_{ij(k)lm}$ is observation $ij(k)lm$, μ is the overall mean, SQ_m is the effect of square m , $ROW(SQ)_{im}$ is the effect of row i within square m , $COL(SQ)_{jm}$ is the effect of column j within square m , $\tau(k)$ is the effect of treatment k , t_l is effects of sampling time, P_n is effects of period, $\varepsilon_{ij(k)lm}$ is random error with mean 0 and variance σ^2 , r is the number of treatments and the number of rows and columns within each square and b is the number of squares.

Table 1. Diet ingredients and chemical composition of experimental diets used in *in vivo* feeding trial (g kg^{-1} of dry matter basis).

| Ingredients | Group 1* | Group 2 | Group 3 | Group 4 |
|---------------------------------|----------|---------|---------|---------|
| SRS | 0 | 120 | 240 | 360 |
| Alfalfa hay | 305 | 255 | 205 | 165 |
| Corn silage | 500 | 430 | 360 | 280 |
| Barely | 60 | 60 | 60 | 60 |
| Soybean meal | 130 | 130 | 130 | 130 |
| Min/vitamin premix [†] | 4 | 4 | 4 | 4 |
| White Salt | 1 | 1 | 1 | 1 |
| ME (Mcal kg^{-1} DM) | 2.35 | 2.33 | 2.31 | 2.29 |
| Crude Protein | 152.00 | 151.00 | 150.30 | 149.40 |
| NDF | 525.00 | 524.10 | 520.00 | 560.00 |
| ADF | 259.20 | 263.80 | 280.00 | 310.00 |
| Ash | 110 | 130 | 150 | 173 |
| Calcium | 5 | 5 | 5 | 5 |
| Phosphorus | 3 | 3 | 3 | 3 |

* Group 1, group 2, group 3 and group 4 represent substitution of 0 (control), 15.00, 30.00 and 45.00% of alfalfa hay and corn silage with sunflower residues silage.

[†] Each kg contained vitamin A, 500000 IU; vitamin D3, 100000 IU; vitamin E, 100 mg; Ca, 190000 mg; P, 90000 mg; Na, 50000 mg; Mg, 19000 mg; Fe, 3000 mg; Cu, 300 mg; Mn, 2000 mg; Zn, 3000 mg; Co, 100 mg; I, 100 mg; Se, 1 mg and antioxidant (BHT), 3000 mg. SRS: Sunflower residue silage; ME: Metabolizable energy; NDF: Neutral detergent fiber; and ADF: Acid detergent fiber.

Results

Chemical compositions of untreated and ensiled SRS are shown in Table 2. Ensiling was being able to increase CP content, reduce NDF and ADF and increase ADL content in sunflower heads, but not in sunflower stalks. SRS for *in vivo* study was prepared by mixing 60:40 ratios of heads to stalks. Mixed silage showed the same manner in increasing CP and ADL content and reduction of NDF and ADF.

Dry matter intake of experimental groups is shown in Table 3. Dry matter intake decreased with increasing levels of SRS in the diets. The DMI was significantly different between the treatments and the highest and the lowest values were obtained in group 3 and group 4, respectively ($p < 0.05$). Dry matter intake was not different among control and groups 2 and 3.

Table 2. The chemical composition of different parts of untreated and ensiled sunflower residues (g 100 g⁻¹ dry matter).

| Composition | Stalks | | | Heads | | | Whole plant* | | |
|-------------------------|--------------------|--------------------|-------|--------------------|--------------------|-------|--------------------|--------------------|-------|
| | Untreated | Ensiled | SEM | Untreated | Ensiled | SEM | Untreated | Ensiled | SEM |
| Crude protein | 2.26 ^b | 5.92 ^a | 0.021 | 2.77 ^b | 9.87 ^a | 0.422 | 2.48 ^b | 8.57 ^a | 0.318 |
| Neutral detergent fiber | 85.09 ^a | 73.91 ^b | 2.124 | 55.32 ^a | 33.11 ^b | 3.144 | 61.24 ^a | 49.81 ^b | 2.847 |
| Acid detergent fiber | 72.72 ^a | 59.42 ^b | 3.048 | 45.69 ^a | 31.89 ^b | 3.214 | 52.35 ^a | 40.64 ^b | 2.431 |
| Acid detergent lignin | 15.25 | 16.38 | 0.852 | 2.41 ^b | 13.25 ^a | 0.714 | 8.15 ^b | 13.11 ^a | 0.521 |

Means within each row in each part (heads, stalks or whole plant) with different superscripts are significantly different ($p < 0.05$).

* Whole plant (60:40 of heads to stalks). SEM: Standard error of means.

Table 3 also shows significant differences among treatments in the case of *in vivo* nutrients digestibility coefficients ($p < 0.05$). Feed efficiency (FE) and feed conversion ratio (FCR) parameters were reported in Table 3. The FE was not significantly different between diets, but there was a significant trend in the case of FCR among group 4 and other groups ($p = 0.08$). Generally, FCR increased with increasing SRS level in the diets.

Milk yield and composition data are shown in Table 3. Milk yield decreased with increasing levels of SRS and differences were statistically significant in the highest substitution level compared to control. Milk composition percentage was similar among diets, but daily production of milk components decreased with 60.00 and 90.00% SRS replacement ($p < 0.05$). Effects of dietary treatments on blood parameters are shown in Table 4. As shown, unless LDL levels, there are no significant differences among treatments. Increasing levels of SRS significantly decreased serum LDL levels.

Discussion

Sunflower residue silage had higher CP content compared to dry sunflower residue and corn silage, which can be explained with supplementary urea in the ensiling process.¹⁴ Urea was reported to be used to improve the nutritive value of poor quality roughages; mainly cereal

straws. Aqueous urea solutions release ammonia under anaerobic conditions.¹⁵ Alkalinity of ammonia efficiently disrupts lignin-carbohydrates bonds and improves fiber digestibility.¹⁵ Reduced NDF and ADF contents in ensiled materials compared to the dry residues can be illustrated by microbial degradation of carbohydrates released from disrupted lignin-carbohydrates complexes during ensiling.^{14,15} However, ADL was increased in sunflower heads and mixed SRSs. In agreement with our results, treatment of bluejack oak (*Quercus incana*) with urea has been resulted in a significant increase in the ADL content.¹⁶ Higher lignin contents of urea treated materials can be concomitant to reduce cellulose content or the presence of polymerized acid detergent insoluble products.¹⁶ Ben Salem *et al.* have shown that urea treatment for tannin deactivation in tanniferous fodder shrubs amplifies ADL content.¹⁷ Fresh and ensiled sunflower residue had lower DM and organic matter contents than corn silage, which can illustrate the subtractive trend in diet DM and OM with increasing dietary levels of SRS. It was reported that sunflower silage had low DM and high ADF contents having deleterious effects on silage quality.¹⁸ However, ensiling increased DM content from 0.25 g kg⁻¹ to 0.39 g kg⁻¹.¹⁸

Dry matter intake decreased with increasing level of SRS in the diets and may partly be due to the increase in NDF content of rations. The neutral detergent fiber was

Table 3. Dry matter intake, nutrient digestibility and milk yield and composition in different experimental groups.

| Parameters | Group 1* | Group 2 | Group 3 | Group 4 | SEM |
|---------------------------------------------------------------------|------------------------------|---------------------|---------------------|---------------------|-------|
| | Production parameters | | | | |
| Dry matter intake (kg per day) | 1.43 ^a | 1.45 ^a | 1.37 ^a | 1.06 ^b | 0.061 |
| Milk yield (kg per day) | 1.13 ^a | 1.10 ^a | 0.91 ^{ab} | 0.76 ^b | 0.071 |
| Feed efficiency | 0.837 | 0.788 | 0.652 | 0.773 | 0.042 |
| Feed conversion ratio | 1.39 ^b | 1.41 ^b | 1.66 ^b | 2.33 ^a | 0.113 |
| Milk composition (g 100 g⁻¹ of milk) | | | | | |
| Crude protein | 3.33 | 3.45 | 3.38 | 3.45 | 0.061 |
| Fat | 4.32 | 4.83 | 5.11 | 4.91 | 0.163 |
| Lactose | 4.57 | 4.58 | 4.56 | 4.54 | 0.052 |
| Total solids | 13.00 | 13.63 | 13.83 | 13.72 | 0.204 |
| Digestibility coefficients (g kg⁻¹ of dry matter) | | | | | |
| Dry matter | 755.10 ^a | 754.80 ^a | 728.30 ^a | 574.90 ^b | 18.62 |
| Crude protein | 769.70 ^a | 765.70 ^a | 785.50 ^a | 659.50 ^b | 16.22 |
| Organic matter | 771.70 ^a | 755.50 ^a | 749.60 ^a | 573.20 ^b | 18.93 |
| Neutral detergent fiber | 695.90 ^a | 708.70 ^a | 733.90 ^a | 461.80 ^b | 23.41 |

* Group 1, group 2, group 3 and group 4 represent substitution of 0 (control), 15.00, 30.00 and 45.00% of alfalfa hay and corn silage with sunflower residues silage.

^{ab} Means within each row with different superscripts are significantly different ($p < 0.05$).

Table 4. Concentrations of blood metabolites in different experimental groups (mg dL⁻¹).

| Metabolites | Group 1* | Group 2 | Group 3 | Group 4 | SEM |
|-----------------|--------------------|---------------------|--------------------|--------------------|-------|
| Glucose | 48.87 | 49.05 | 48.12 | 49.12 | 0.962 |
| Triacylglycerol | 21.78 | 21.84 | 21.37 | 18.26 | 0.941 |
| Cholesterol | 91.21 ^a | 85.71 ^{ab} | 76.53 ^b | 72.71 ^b | 3.082 |
| HDL | 40.15 | 34.87 | 42.42 | 40.15 | 1.812 |
| LDL | 46.71 ^a | 46.49 ^a | 29.83 ^b | 28.91 ^b | 3.012 |
| VLDL | 4.35 | 4.37 | 4.27 | 3.65 | 0.191 |

* Group 1, group 2, group 3 and group 4 represent substitution of 0 (control), 15.00, 30.00 and 45.00% of alfalfa hay and corn silage with sunflower residues silage.

^{ab} Means within each row with different superscripts are significantly different ($p < 0.05$).

HDL: High density lipoproteins; LDL: Low density lipoproteins; and VLDL: Very low density lipoproteins.

reported to be an effective DMI controlling factor in ruminants.¹⁹ Besides, unpalatable lignocellulosic structure and relatively large particle size of the sunflower stalks could be considered as a causative limiting factor. As mentioned earlier, the SRS in this study was made up of two parts, heads and stalks. The head is more palatable and digestible, but stalks have unpalatable lignocellulosic structure and are lower in digestibility compared to the sunflower head.⁷ Generally, stalks were refused by animals and remained in the trough.⁸ Additionally, higher moisture content in diets with higher proportions of SRS can cause DMI reduction.^{20,21} Lower digestibility of diets with higher SRS is also accounted in decreased DMI.²¹⁻²³ Amini-Jabalkandi *et al.* have found that increasing level of SRS in diets of fattening Azeri male buffaloes significantly reduces daily DMI.⁹ Heifers fed by sunflower silage were reported to have a lower DMI than alfalfa-grass silage fed animals.²⁴ In another study, feed intake in corn silage fed Holstein dairy cattle was higher than sunflower silage consumed group.²⁵ Lower DM content of sunflower silage compared to corn silage and grass-alfalfa silage has been mentioned as an effective DMI reducing factor.^{24, 25} Thomas *et al.* have also reported that cows consuming sunflower silage have lower feed intake and produce less milk with lower protein and solid than corn silage fed cows.²⁶

Feed efficiency was not significantly different between diets, but there was a significant trend in the case of FCR among group 4 and other groups. Generally, FCR increased with increasing SRS level in the diets.

Nutrient digestibility was significantly different between the treatments. The DM and OM digestibilities were decreased with increasing level of SRS among the diets. The highest and the lowest values were obtained in control and 45.00% SRS fed animals, respectively. The higher fiber content of SRS compared to alfalfa and corn silage may be able to describe the observed decline in the nutrient digestibility in animals fed SRS-rich diet. *In vitro* DM digestibility of sunflower residue was reported to be 0.71 and ammonia treatment could elevate it to 0.73.⁵ Demirel *et al.* have reported that increasing sunflower

silage proportion in mixed sorghum and sunflower silages increases DM, CP and fat digestibility, but concomitantly reduces NDF and ADF digestibility.²⁷ Lower DM and OM digestibility in group 4 in our experiment could be a secondary effect of lower CP digestibility. Holstein male calves received soybean meal in addition to sunflower silage had higher OM digestibility compared to the control group, may be as a result of increased ruminal available nitrogen for microbial digestion.²⁶

Christensen has stated very low OM digestibility for SRS and has reported that 0.54 of OM was eliminated.²⁸ However, *in vivo* digestibility coefficients for sunflower residue samples of Kerman province in Iran were reported as 0.60, 0.63, 0.38, 0.37 and 0.44 for DM, CP, crude fiber, NDF, and ADF, respectively.²⁹

Feed efficiency was calculated as an amount of fat corrected milk produced for one kilogram of consumed DM. Dietary treatments could not significantly change FE. Although, increased inclusion rate of SRS resulted in a lower milk yield together with reduced DMI. This can be precisely explained by the same FE between diets. Feed conversion ratio was higher for the highest inclusion rate of SRS.

Daily live weight changes were not affected by dietary forage type and could be related to low milk production of animals fed higher SRS in the diet. The same DMI, milk production and nutrient digestibility among control and low and moderate (15.00 and 30.00%, respectively) SRS fed goats could partially describe the results. So, it can be concluded that lower nutrient availability associated with higher dietary SRS levels resulted in lower milk production and animals didn't use body reserves for supporting milk production.

The inclusion of more than 30.00% of SRS in the lactation diets was resulted in lower milk production. Milk fat percentage was not significantly different between experimental groups; there was a tendency for a higher milk fat in groups fed 30.00 and 45.00% of dietary forage as a SRS. Even though milk production decreased in animals received 30.00% of their dietary fiber source as a SRS, fat-corrected milk production was not affected. Higher milk fat in SRS fed goats may be explained with a higher fiber content of SRS contained diets. Daily yield of milk components was different between treatments and substitution of 45.00% of dietary forage sources with SRS was resulted in a significant reduction of the daily production of fat, protein, lactose and total solids. Lower daily lactose production can be explained by diet fermentability reduction. This occurs without a reduction of milk lactose percentage indicating that glucose availability is the main limiting factor for milk production.²¹ However, animals in different experimental groups did not exert statistically different plasma glucose levels. It can be concluded that lower milk production is the main factor limiting daily milk component yield. Milk

composition was significantly different between morning and evening milking. Adebosin *et al.* in a study to evaluate the effects of genotype and milking time on milk yield and composition in cross-bred cattle have found that evening milk has higher components compared to morning derived milk.³⁰ However, they have failed to show significant differences. In the present study, there were statistically significant differences in milk components between two milking times ($p < 0.05$).³⁰

There were no differences in blood metabolites among experimental animals, except for LDL levels. Although different performance indices such as milk production, daily lactose production, and diet digestibility coefficients can be used to show lowered fermentability of SRS containing diets, there was no significant difference in blood glucose levels among experimental groups. Similar glucose levels could be attributed to the hemostatic controls resulting in lower glucose availability in mammary glands for lactose production in goats received high SRS contained diets.

The results of this experiment indicated that SRS is a partially acceptable forage source for dairy goats and common dietary forages can be replaced up to 30.00% with SRS without affecting milk production and composition.

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Conflict of interest

The authors declare that there is no conflict of interest.

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