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Milk Production, Milk Composition, Milk Fatty Acid Profile and Nutrient Digestibility of Mehsana Goats Fed Sunflower (*Helianthus annus*) Oil

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ABSTRACT

A study was conducted during the month of December, 2020 to January, 2021 at Livestock Research Station, Kamdhenu University, Sardarkrushinagar, Gujarat (385506), India to evaluate the effect of dietary sunflower oil supplementation on milk yield, milk fatty acid profile and nutrient digestibility of Mehsana goats. Eighteen lactating Mehsana goats were randomly divided into three treatment groups, viz. Basal diet (control), Basal diet+25 g animal^{-1} day^{-1} of sunflower oil and Basal diet+50 g animal^{-1} day^{-1} of sunflower oil for a period of 60 days. No significant differences (p>0.05) were found in milk yield in terms of kg d^{-1}, 4% fat corrected milk and energy corrected milk among the treatment groups. The milk constituents and their yields were not affected due to dietary inclusion of sunflower oil. Sunflower oil feeding at the dose of 50 g d^{-1} increased (p<0.05) concentration of milk short chain fatty acids and polyunsaturated fatty acids in the milk of goats. The intake and digestibility of nitrogen free extract was increased in sunflower oil supplemented groups. The intake and digestibility of dry matter, organic matter, crude protein, ether extract and crude fibre were similar (p>0.05) among the treatment groups. it may be concluded that supplementation of sunflower oil at the dose rate of 25 and 50 g d^{-1} did not affect feed intake, milk yield, milk constituents and nutrient digestibility in lactating Mehsana goats. However, dietary 50 g d^{-1} of sunflower oil significantly increased concentration of milk short chain fatty acids and polyunsaturated fatty acids in goats.

KEYWORDS: Goat, milk yield, milk fatty acids, sunflower oil

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1. INTRODUCTION

In India, goat husbandry practices provide livelihood to millions of poor farmers and landless laborers (Santra et al., 2020; Patil et al., 2022). As per 20th Livestock Census, goat population in India was 148.88 million (Anonymous, 2019). Goats have many features such as low production costs, short generation intervals, low feed requirements, and production of a constant supply of small quantities of milk suitable for immediate household consumption (Miller and Lu, 2019). Goat milk is prized for its unique qualities, and their manageable size makes them ideal for smallholders, including women and children (Chauhan et al., 2021). During the year 2022–23, goat contributed nearly 14.47% of total meat production, while milk shares contribution was 3.30% in the total milk production across the country (Anonymous, 2023). Goat is projected as future food animal as there are availability of a wide variety of goat breeds and there is high market demand for goat meat and milk (Dhaliwal et al., 2022). Mehsana goats are dual-purpose breed and are raised for both milk and meat production (Modi et al., 2022). The early lactation period is normally characterized by a status of negative energy balance because the intake of nutrients and energy are insufficient to meet the high energy demands of milk production (Pérez-Báez et al., 2019). Additionally, farmers are facing constraint of availability of good quality fodder resources to meet the nutrient requirement (Pawar et al., 2019). The negative energy balance in goats may affect their body condition score and milk production (Reshma et al., 2022). Providing high energy density diet helps to maintain body condition score, allows for increments in the yields of milk/milk fat and improvement in reproductive performance of lactating animals (Castro et al., 2019; Sadrasaniya et al., 2022). Dietary supplementation of vegetable oil such as sunflower oil as an additional source of energy in early lactating goats could overcome this problem. Earlier studies have reported benefits of sunflower oil supplementation in lactating animals include increased energy concentration in the diet, reduced supply of rapidly fermentable carbohydrates and better productive performance (Morsy et al., 2015; Khalifa et al., 2016). Sunflower oil is rich source of linoleic, linolenic acid and provides polyunsaturated fatty acids (Ojha et al., 2024). Sunflower oil contains 64.1 and 25.2% of linoleic acid (cis–9, cis–12 C18:2) and oleic acid (cis–9 C18:1), respectively (Mwakasege et al., 2021).

Milk fat content and fatty acid composition can be significantly altered through dietary strategies such as inclusion of vegetable oils, offering the opportunity to respond to changes in consumer requirements and provide foods more in line with recommendations for improving human health (Joshi et al., 2021). Sunflower oil inclusion in the diet may alter milk fatty acid profile, with some potential benefits for the people consuming the milk (Netto et al., 2022; Wanderley et al., 2022). Recent studies found that supplementation of sunflower oil in dairy animals modified fatty acid composition of milk towards a healthier profile for human consumption (Ferlay and Chilliard, 2020; Lopes et al., 2021; Ahuja et al., 2023; Patel et al., 2023). We hypothesized that supplementation of sunflower oil during early lactation in Mehsana goats will to bring improvement milk yield and fatty acid composition through modified ruminal biohydrogenation and mammary lipogenesis. Thus, the objective of this study is to determine the effect of sunflower oil supplementation on milk yield, composition, fatty acid profile and nutrient digestibility of Mehsana goats.

2. MATERIALS AND METHODS

The use of animals and experimental protocol followed in this study was approved (No. VETCOLL/IAEC/2021/18/PROTOCOL-3) by the Institutional Animal Ethics Committee. This study was conducted at Livestock Research Station, Sardarkrushinagar which is located in semi-arid region of North Gujarat, India having latitude of 24.32' North and longitude of 72.31' East and at an elevation of 189 meters above the mean sea level. This experiment was carried out during the month of December, 2020 to January, 2021. Eighteen lactating Mehsana goats were randomly divided into three treatment groups, viz. Basal diet (control), Basal diet+25 g animal^{-1} day^{-1} of sunflower oil and Basal diet+50 g animal^{-1} day^{-1} of sunflower oil for a period of 60 days. The experimental animals were fed roughages and concentrate mixture at the ratio of 60:40 to meet their nutrient requirements (Anonymous, 2013).

Goats were milked twice a day and individual milk yield for each goat was recorded daily by using electronic weighing balance. The 4% fat corrected milk (FCM) was calculated as per Gains (1928): milk yield (kg)×0.4+fat yield (kg)×15. Energy corrected milk (ECM) was calculated as per Davidson et al. (2008): 0.327×milk yield (kg day^{-1})+12.86×fat yield (kg day^{-1})+7.65×protein yield (kg day^{-1}). Milk samples were collected at fortnightly interval for analysis of milk composition (fat, solids-not fat (SNF), protein and lactose) using EKOMILK Ultra Pro Milk Analyzer (Everest Instruments Pvt. Ltd.). Milk fatty acids were analyzed by isolating milk fat by centrifugation and methylation using sodium methylate according to O'Fallon et al. (2007). Fatty acid methylesters were analyzed using a gas chromatograph (Thermo Scientific Ceres 800) with flame ionization detector and capillary column (60 m×0.25 mm×0.20 mm). The initial oven temperature was 120°C, held for 5 min, subsequently increased to 240°C at a rate of 2°C per min, and then held for 60 min. Nitrogen at a flow rate of 1 ml min^{-1} was used as the carrier gas. Both the injector and the detector were set at 260°C. The split ratio was 30:1. As an internal standard fatty acid Heptadecanoic acid C17:0 (Catalogue number H3500, Sigma-Aldrich, Bangalore, India) was used and a mix of FAME standards (Supelco 37 Component FAME Mix, Sigma Aldrich, Bangalore, India) was used to generate a calibration curve. Fatty acids were identified by comparing their retention times with the fatty acid methyl standards and were expressed as percentage of total fatty acids.

A digestion trial of 5 days' collection was conducted after 60 days of experimental feeding. Daily feed offered, residue and faeces were collected individually. After measuring the total amount, representative samples of feed offered, residual feed and faeces were preserved for the further analysis. The samples were dried at 60°C in a forced air oven for 48 h, ground to pass through a 1-mm screen using a Wiley mill. The samples of feeds and fodders were analyzed for dry matter (DM, method 934.01), crude protein (method 976.05), crude fibre (method 978.10), ether extract (method 973.18) and total ash (method 942.05) (Anonymous, 2007). The chemical composition of feeds and fodders fed to experimental animals is given in Table 1.

Table 1: Chemical composition (% on DM basis) of feeds and fodders

Composition (%)	Concentrate mixture	Green maize	Gaur straw
Dry matter	91.80	26.00	90.32
Crude protein	20.31	8.87	11.00
Crude fibre	7.24	27.37	45.5
Ether extract	3.25	1.72	1.20
Ash	6.58	6.89	6.62
NFE	62.62	55.15	35.68

All the experimental data obtained were statistically analyzed by using SPSS v.20.0 (SPSS Inc., Chicago IL) as per the standard statistical methods (Snedecor and Cochran, 1994). The differences between the means were determined using Duncan multiple range test. Significant difference was accepted at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Feed intake, milk production, milk constituents and feed efficiency

The effects of sunflower oil supplementation on feed intake, milk production, milk constituents and feed efficiency of Mehsana goats are given in Table 2. There was no difference ($p>0.05$) in DM intake of lactating goats among the dietary treatments. The vegetable oils are rapidly released in the rumen and have subsequent potential harmful effects on the rumen microbes, fibre degradation and feed intake. Hence, to avoid a decrease in feed intake, the NRC (2001) had recommended that ruminant rations with a maximum of 6–7% of fat (on % DM basis). In this study, the fat content in the ration of lactating goats were below the recommended level and the roughage:concentrate ratio

Table 2: Effect of sunflower oil supplementation on milk production, constituents and feed efficiency of Mehsana goats

Attributes	T_1	T_2	T_3	SEm	p value
Dry matter intake (DMI)					
DMI (g d^{-1})	1033.83	1034.00	1026.12	4.337	0.723
DMI (% of BW)	3.03	2.83	2.80	0.053	0.163
DMI (g kg^{-1} W0.75)	73.25	69.59	68.91	0.986	0.156
Yield (g d^{-1})					
Milk	746.77	760.07	778.47	24.066	0.878
4% FCM	547.48	569.02	578.19	18.498	0.805
ECM	643.13	662.51	675.41	21.171	0.839
Fat	16.58	17.67	17.79	0.612	0.703
Solids not fat	54.87	58.45	59.66	2.006	0.627
Total solids	71.46	76.11	77.45	2.569	0.635
Protein	24.08	24.21	24.90	0.775	0.907
Lactose	21.59	22.72	23.78	0.737	0.514
Milk constituents (%)					
Fat	2.21	2.33	2.28	0.030	0.290
Solids not fat	7.33	7.69	7.65	0.073	0.088
Total solids	9.54	10.01	9.93	0.081	0.127
Protein	3.24	3.19	3.19	0.035	0.858
Lactose	2.91	3.02	3.05	0.022	0.218
Feed efficiency					
Milk (g) DMI^{-1} (g)	0.73	0.74	0.77	0.024	0.866
4% FCM (g) DMI^{-1} (g)	0.54	0.56	0.57	0.019	0.820
ECM (g) DMI^{-1} (g)	0.63	0.65	0.66	0.022	0.852

DMI: Dry matter intake; FCM: Fat corrected milk; ECM: Energy corrected milk

(60:40) may have minimized the effects of supplemental fat on rumen microbial fermentation and had no negative effect on dry matter intake and milk yield. In line with the present findings, no difference in DM intake were reported in dairy animals supplemented with sunflower oil (Lopes et al., 2020; Ahuja et al., 2023; Patel et al., 2023). In contrast, Kairenius et al. (2018) found that DM intake was reduced in dairy cows fed grass silage-based diet supplemented with 500 g d^{-1} of sunflower oil.

No significant (p>0.05) effect was found in milk yield in terms of g d^{-1}, 4% FCM and ECM among the treatment groups. Dietary supplementation of sunflower oil at 25 and 50 g d^{-1} had no effect (p>0.05) on the yields of milk fat, SNF, total solids, protein and lactose. The lack of influence on milk production performance in lactating goats due to supplementation of sunflower oil in the present study is supporting the fact that normally vegetable oils have no effect on milk yield in dairy animals (Ahuja et al., 2023; Patel et al., 2023). The presence of higher polyunsaturated fatty acids in sunflower oil may reduce mobilization of body reserves and the lower use efficiency of the dietary energy for milk production (Rufino et al., 2018). In agreement with the present findings, earlier studies reported that there was no effect (p>0.05) of sunflower oil supplementation on milk production in dairy animals (De Souza et al., 2019; Ferlay and Chilliard, 2020; Lopes et al., 2020). On the contrary, Rufino et al. (2018) observed that there was significant (p<0.05) reduction in daily milk yield in Jersey cows fed sunflower oil than the control.

The percentage of milk fat, SNF, total solids, protein and lactose were not affected (p>0.05) by the dietary sunflower oil. Similar to the present findings, recent studies (Lopes et al., 2020; Vargas-Bello-Pérez et al., 2020) reported that milk fat, protein, lactose and total solids contents were not influenced (p>0.05) due to dietary sunflower oil supplementation in dairy cows and ewes. On the contrary to the present findings, Rufino et al. (2018) and De Souza et al. (2019) found that sunflower oil supplementation in dairy cows reduced (p<0.05) milk fat percentage. In present study, supplementation of sunflower oil did not induce milk fat depression. This might be due to feeding of ration which provides enough amount of effective fiber (Bionaz et al., 2020). There was no significant (p<0.05) difference in feed efficiency among the treatment groups. This was the reflection of no difference in milk production and feed intake among the treatment groups. The lack of effect on feed efficiency may be attributed to similar DM intake across the treatment groups. This is in line with the results of Ahuja et al. (2023) and Patel et al. (2023) who reported that supplementation of sunflower oil in lactating cows and buffaloes had no effect on the feed efficiency.

3.2. Milk fatty acid profile

The effect of supplementation of sunflower oil on milk fatty acid profile (g 100 g^{-1} FA) of Mehsana goats is presented in Table 3. The concentration of short chain fatty acids *viz.,* C4:0 (Butyric acid) and C6:0 (Caproic acid) was significantly (p<0.05) increased in sunflower oil supplemented groups than the control. The percentage of C18:2n6c (Linoleic acid) was significantly (p<0.05) higher in T_3 group as compared to the T_1 and T_2 groups. The dietary

Table 3: Effect of supplementation of sunflower oil on milk fatty acid profile (g 100 g^{-1} FA) of Mehsana goats

Milk fatty acids	T_1	T_2	T_3	SEm	p value
C4:0 (Butyric acid)	0.95[a]	1.20[b]	1.30[b]	0.050	0.001
C6:0 (Caproic acid)	2.02[a]	2.26[ab]	2.40[b]	0.065	0.027
C8:0 (Caprylic acid)	2.92	3.06	3.26	0.082	0.237
C10:0 (Capric acid)	9.47	8.90	9.12	0.258	0.704
C11:0 (Undecanoic acid)	0.03	0.01	0.02	0.007	0.735
C12:0 (Lauric acid)	5.13	5.23	4.89	0.189	0.782
C13:0 (Tridecanoic acid)	0.05	0.06	0.08	0.012	0.693
C14:0 (Myristic acid)	10.89	12.05	11.06	0.334	0.338
C15:0 (Pentadecanoic acid)	1.80	1.67	1.93	0.105	0.642
C16:0 (Palmitic acid)	22.89	22.10	21.67	0.390	0.472
C16:1 (Palmitoleic acid)	1.08	1.14	1.03	0.212	0.982
C17:0 (Heptadecanoic acid)	2.10	2.02	2.09	0.087	0.941
C18:0 (Stearic acid)	14.80	14.91	14.41	0.574	0.944
C18:1n9t(Elaidic acid)	19.49	17.76	17.18	0.483	0.119
C18:1n9c (Oleic acid)	0.36	0.49	0.77	0.090	0.158
C18:2n6t (Linolelaidic acid)	0.08[a]	0.42[b]	0.46[b]	0.063	0.009
C18:2n6c (Linoleic acid)	3.32[a]	3.37[a]	4.45[b]	0.216	0.034
C18:3n3 (gamma-Linolenic acid)	1.11[a]	1.66[ab]	1.79[b]	0.137	0.086
C20:0 (Arachidic acid)	0.71	0.71	0.77	0.044	0.846
C20:1 (cis-11-Eicosenoic acid)	0.05	0.09	0.08	0.026	0.831
C20:4n6 (Arachidonic acid)	0.42	0.38	0.57	0.054	0.348

Table 3: Continue...

Milk fatty acids	T_1	T_2	T_3	SEm	p value
C22:0 (Behenic acid)	0.34	0.48	0.44	0.038	0.314
C24:0 (Lignoceric acid)	0.02	0.05	0.04	0.014	0.706
Saturated fatty acids	74.07	74.63	73.45	0.646	0.792
Unsaturated fatty acids	25.93	25.37	26.55	0.646	0.792
Monounsaturated fatty acids	20.97	19.47	19.05	0.485	0.253
Polyunsaturated fatty acids	4.96[a]	5.90[a]	7.50[b]	0.397	0.011

[ab]Means with different superscripts in a row differed significantly (p<0.05)

supplementation of sunflower oil significantly (p<0.05) increased milk polyunsaturated fatty acids in T_3 (7.50%) group as compared to the T_1 (4.96%) and T_2 (5.90%) groups. Sunflower oil is a rich source of unsaturated fatty acids and it has the ability to enhance the fatty acid profile of milk fat (Ahuja et al., 2023). Feeding oils increases unsaturated fatty acids in milk by escaping from biohydrogenation in the rumen (Grummer, 1991; Oliveira et al., 2021). Similarly, earlier studies also reported that supplementation of sunflower oil led to higher concentrations of milk unsaturated fatty acids in dairy animals (Salles et al., 2019; De Souza et al., 2019; Lopes et al., 2020). Additionally, dietary addition of castor oil and its component ricinoleic acid beneficially improved milk fatty acid profile in lactating cows (Joshi et al., 2021; Pawar et al., 2021).

3.3. *Nutrient digestibility*

The intake and digestibility of nitrogen free extract was improved in both the sunflower oil supplemented groups (Table 4). The intake and digestibility of dry matter, organic matter, crude protein, ether extract and crude fibre were similar (p>0.05) among the treatment groups. Generally, supplemental level of vegetable oil less than 5% of dry matter intake in ruminant will not have any adverse effect on digestibility of dry matter and crude fibre. In the present study supplemental levels of sunflower oil were below the above-mentioned levels. In agreement with the present findings, Lopes et al. (2020), Vargas-Bello-Pérez et al. (2020) and Ahuja et al. (2023) reported that there was no effect (p>0.05) on dry matter, organic matter, crude protein and crude fibre digestibility in cows and goats supplemented with sunflower oil. On the contrary, increased (p<0.05) ether extract digestibility was reported in dairy cows fed sunflower oil (Rufino et al., 2018; De Souza et al., 2019; Ahuja et al., 2023).

Table 4: Effect of sunflower oil supplementation on nutrient intake and digestibility in Mehsana goats

Attributes	T_1	T_2	T_3	SEm	p value
Nutrient intake (g d^{-1})					
Dry matter	1091.67	1092.42	1077.85	3.642	0.191
Crude protein	136.06	135.10	135.70	0.821	0.907
Ether extract	17.01	17.64	17.34	0.517	0.901
Crude fibre	350.44	351.45	350.47	2.347	0.984
Nitrogen free extract	440.66[a]	508.0[ab]	574.08[b]	22.858	0.038
Apparent nutrient digestibility (%)					
Dry matter	52.03	51.59	51.82	0.688	0.973
Organic matter	70.90	72.29	74.39	0.698	0.113
Crude protein	62.38	62.79	63.77	0.728	0.765
Ether extract	44.03	45.71	46.34	0.672	0.385
Crude fibre	62.74	63.55	62.65	2.870	0.905
Nitrogen free extract	51.59	57.29	58.00	1.486	0.155

[ab]Means with different superscripts in a row differed significantly (p<0.05)

4. CONCLUSION

Supplementation of sunflower oil at the dose rate of 25 and 50 g d^{-1} did not affect feed intake, milk yield, milk constituents and nutrient digestibility in lactating Mehsana goats. However, dietary 50 g d^{-1} of sunflower oil significantly increased concentration of milk short chain fatty acids and polyunsaturated fatty acids in goats.

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