



Potential of chia oil to enrich goats' milk with omega-3 fatty acids in comparison to linseed oil under tropical climate

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ABSTRACT

To study the potential of Chia oil to enrich goats' milk with omega-3 fatty acids in comparison to Linseed oil (LSO) under tropical climate, twelve lactating goats (Beetal) divided into 3 groups (on the basis of milk yield and parity) and were randomly assigned control diet or supplemented with Linseed oil (LSO) or Chia oil as additive at 1% of dry matter intake for 60 days. Dietary inclusion of Linseed or Chia oil didn't affect DM intake, apparent dry matter digestibility, pH or total volatile fatty acid production in dairy goats, however, acetate and butyrate in LSO group and ammoniacal-N in Chia group were higher than control. Similarly, no significant changes were detected for milk yield and milk composition, but values were numerically higher in LSO and Chia supplemented groups in comparison to control group. Inclusion of Linseed oil improved proportion of α -linolenic acid in milk fat. Moreover, eicosapentaenoic acid and docosahexaenoic acid were significantly improved in LSO group only. Poly unsaturated fatty acid content in milk varied from 3.09 g/100 g fat (control) to 3.86 g/100 g fat in LSO supplemented group but the differences were statistically non-significant. The proportions of omega 3 fatty acids was enhanced by 75.0 and 31.9% in LSO and Chia groups over control group that led to decrease in ratio of n-6/n-3 FA and desaturase index. It can be concluded that dietary inclusion of both oils improved the fatty acid profile of goat's milk, but Chia oil is not as effective as Linseed oil under tropical climate.

Key words: Chia oil, Goat milk, Linseed oil, Omega 3 fatty acids, Tropical climate

Milk, the nature's most complete food, is considered as an excellent source of beneficial metabolites, such as conjugated linoleic acid (CLA), omega-3 (n-3) and omega-6 (n-6) fatty acids (FA), antioxidants, phenols, flavonoids, and bioactive peptides which have major impact on human metabolism and health (Hilario *et al.* 2010, Prandini *et al.* 2011). However, the consumption of foods of animal origin has been discouraged by the people as meat and milk fat in ruminant products have higher concentrations of saturated fatty acids (SFA) and lower concentrations of polyunsaturated fatty acids (PUFA) which have negative consequences on human health (Schettino *et al.* 2017). In order to balance FA profile of ruminant dairy products through nutritional interventions, supplementation of lipid sources (oil seeds like linseed, safflower, sunflower etc.) were used to alter the fatty acid profile of milk fat (Nudda *et al.* 2003, Bernard *et al.* 2009).

Among oil seeds, Linseed (*Linum usitatissimum*) is considered as a leading source of plant based n-3 FA as it

contains about 40% oil, with a high level of α -linolenic acid (ALA; 50% to 60% of total FA) and it also contains a lower concentration of linoleic acid (LA) and saturated FA (SFA) compared with other oilseeds such as soybean, cottonseed, corn and sunflower (Legrand *et al.* 2010). Recently, Chia oil has become a potential source of oil in human diet as an ingredient to prepare food because of its desirable fatty acid profile. Chia seeds, which are native to USA/Mexico, contain 25–40% of fat, most of which is in the form of polyunsaturated fatty acids, such as n-3, α -linolenic acid (about 60%) and n-6, α -linoleic acid. Moreover, Chia seeds take root in India with efforts of government agencies in Rajasthan, Karnataka, Gujarat, Tamil Nadu, Bihar etc. recently and its seeds are available at the cost of Rs 200/kg, which expected to stabilize around Rs 70/kg in coming years (Express News Service 2015). In addition to potential health benefits, use of Chia oil to modulate milk fat in ruminants have been studied by various researchers (Ayerza and Coates 2006, Schettino *et al.* 2017). But, to the best of author's knowledge, no study was conducted to assess its potential to modulate fatty acid profile of milk in Indian breeds and no scientific literature is available regarding the potential of Chia oil to enhance fatty acid profile of Beetal goat's milk in comparison to Linseed oil under tropical climate, although both are known for higher ALA (α -linolenic acid) content among all oil

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seeds. Hence, keeping these points in background, present study was planned with the hypothesis that the Chia oil has better potential to enrich goats' milk with omega-3 fatty acids in comparison to Linseed oil under tropical climate.

MATERIALS AND METHODS

Location and ethical compliance: Study was conducted in the Goat Farm, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India and experimental protocol was approved (vide IAEC/2017/734-760 dt 20.03.2017) by Institutional Animal Ethics Committee constituted (IAEC) under CPCSEA, New Delhi.

Animals, treatments and feeding management: Twelve lactating goats (Beetal) were selected, assigned to three treatment groups on the basis of milk yield (Average 1232.9 ± 156 mL/d) and parity. All animals were fed individually on a basal/control diet consisting of green fodder-Berseem (*Trifolium alexandrinum*) and concentrate mixture in 60:40 ratio as per NRC (2007). The concentrate mixture was consisted of maize (40%), barley (10%), soybean meal (11%), rice bran (15%), wheat bran (20%), mineral mixture (2%), salt (1%) and buffer (1%). The goats in first group (control group) were offered only basal diet with no additive, whereas goats in treatment groups were supplemented with Linseed oil (LSO group) or Chia oil (Chia group) @ 1% of DMI, respectively along with basal diet. Goats were acclimated to feeding, experimental and environmental conditions for a period of 15 days during which they were given anthelmintic orally (Fendazole-2.5) and daily milk yield (MY) was recorded for subsequent grouping. After that they were subjected to respective treatment for a period of 60 days. The additives (LSO or Chia oil) were mixed with 100 g of the concentrate mixture just before feeding and offered to the goats at 09:00 h. The rest of concentrate mixture and green fodder was offered together at 1000 h and 1500 h in two divided doses. The chemical composition of feedstuffs is shown in Table 1. Linseed (*Linum usitatissimum*) oil and Chia (*Salvia hispanica*) oil were procured from Global Scientific Traders, New Delhi and stored in plastic containers at room temperature. All animals had free access to water and were kept out in the open area post feeding. Goats were hand milked twice daily (0530 and 1630 h) and daily milk yield (MY) was noted for individual goats. The body weight (BW) of animals was recorded every fortnightly using electronic scale balance and feeding schedule modified

accordingly. Feeds and residue samples were dried at 60°C in a hot air oven till a constant weight and daily dry matter intake (DMI) was estimated individually by comparing the feed offered and residue left at 24 h interval.

Digestibility trial: Seven days digestion trial was conducted by indicator method (Hill and Anderson 1958) using chromic oxide green as an external marker @ 0.2% of daily DM intake. Feed and residue (if any) were collected and weighed daily after 24 h. Faecal samples were collected twice daily at 0800 h and 1600 h by grab method, from the rectum of the animal. Feeds, residues and faecal samples were dried at 60°C in a hot air oven till a constant weight and ground in a Wiley mill (Macro Scientific Works Pvt. Ltd., Delhi) to pass a 1 mm sieve. The samples were further processed to analyze ether extract (EE), neutral detergent fibre (NDF), acid detergent fibre (ADF), crude protein (CP) (Van Soest *et al.* 1991, AOAC 2000). Blood samples were collected 4 h post feeding by puncturing the jugular vein at the end of the trial. After collection of blood samples, the serum was separated and stored for glucose estimation (Trinder 1969). Rumen liquor samples were collected through stomach tube from each animal after 4 h post feeding. In rumen liquor samples, protozoal count was done as per the method described by Naga *et al.* (1969).

Milk composition and fatty acid profile: Chemical composition (%) of goat milk, i.e. fat, solid not fat, protein and lactose was analyzed by using milk analyzer "Lactoscan LA" from Milktronic LTD, Bulgaria. For FA profiling of milk fat, fat was extracted from 100 g sample using n-hexane and this extracted fat was esterified by saponification method using Trans Methylene mixture. Samples of LSO, Chia oil, concentrate, fodder and milk fat were analyzed for FA content according to method of Ranganna (1986) using FA methyl esters prepared by liquid partitioning with petroleum ether and distilled water. On a Perkin-Elmer chromatograph equipped with a flame ionization detector (FID), the FAs were separated. Helium was used as carrier gas at 30 cc/sec. The temperature of oven and injector was 250°C and 60–120°C, respectively. Individual FA methyl esters were identified by retention time with reference to methyl esters standards FAME-37 MIX from Supelco (Sigma-Aldrich).

Statistical analysis: The data generated during the experiment were subjected to analysis of variance (ANOVA) using SPSS (2007) software with the following model:

$$Y_{ij} = \mu + T_i + \epsilon_{ij}$$

where Y_{ij} , each observation (DM intake; milk yield etc.); μ , total mean; T_i , effect of i^{th} treatment ($i = C; T1$ and $T2$); ϵ_{ij} , residual error. Tukey's b test was used for the post-hoc comparison of different treatment, means and statistical differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Fatty acid composition of control diet ingredients, Linseed and Chia oil was examined and is furnished in

Table 1. Chemical composition of feedstuffs (% Dry matter basis)

Parameter	Green Fodder	Concentrate
Total ash	9.92	6.02
Organic matter	90.08	93.98
Crude protein	20.10	18.20
Ether extract	3.06	4.25
Cellulose	17.20	8.30
Neutral detergent fibre	39.0	28.30
Acid detergent fibre	24.55	10.50

Table 2. The level of SFA and omega 3 FA (n-3 FA) in Berseem fodder and concentrate mixture were 7.28 and 9.25; 16.04 and 15.6 mg/g DM, respectively. Additionally, the level of monounsaturated fatty acids (MUFA) in concentrate mixture was 13.85 mg/g DM, while in green fodder it was only 1.74 mg/g DM.

The level of polyunsaturated fatty acids (PUFA) was found to be 19.49 and 21.54 mg/g DM in green fodder and concentrate mixture, respectively. Levels of n-3 FA was 536.9 and 609.6 mg/g oil in Linseed and Chia oil, respectively along with higher levels of α -linolenic acid (Table 2). Earlier studies by Glasser *et al.* (2008) and Morsy *et al.* (2015) also reported that linseed oil contained high level of omega 3 FA, particularly α -linolenic acid (ALA; 50% to 60% of total FA). Similarly, Chia oil has high content of α -Linolenic acid (about 60%), linoleic acid, oleic acid and stearic acid (Alvarez *et al.* 2008; Schettino *et al.* 2017). Supplementation of oil sources in the diet led to higher ($P<0.01$) intake of major FA (Table 3) in LSO and Chia groups as compared to control group. It was observed that the intake of PUFA was increased ($P<0.01$) by 29.56 and 18.53% in LSO and Chia groups, respectively as compared to control group. Moreover, the intake of n-3 FA was recorded to be higher in LSO and Chia groups ($P<0.01$) by 50.86 and 47.55%, respectively as compared to control group.

Results revealed that there was no ($p>0.05$) effect on DMI, apparent digestibility of DM, ruminal pH or total volatile fatty acid production with dietary inclusion of Linseed or Chia oil @ 1% of DM intake (Table 4). These findings are in concordance with Kholif *et al.* (2015) who observed that dietary supplementation of linseed oil didn't affect DM intake in lactating goats. Similar findings were

Table 3. Daily intake of major FA by different experimental group, g/100g FA

Fatty acid	Diet			SEM	P value
	Control	LSO	Chia oil		
C12:0	0.087	0.086	0.080	0.003	0.117
C14:0	0.219	0.222	0.208	0.003	0.097
C16:0	8.491 ^a	9.355 ^b	8.687 ^a	0.074	0.007
C18:0	1.115 ^a	1.912 ^c	1.543 ^b	0.055	0.005
C14:1	0.255	0.250	0.233	0.013	0.527
C18:1n-	8.579	11.170	10.893	0.912	0.084
C18:2n-6	15.269	16.746	13.977	1.113	0.116
C18:3n-6*	0.165 ^a	0.230 ^b	0.176 ^{ab}	0.012	0.064
C18:3n-3***	14.20 ^a	21.51 ^b	21.06 ^b	0.169	0.000
C20:4n-6	0.073	0.071	0.0678	0.001	0.110
C20:5n-3	0.053	0.052	0.048	0.009	0.219
C22:6n-3**	0.0026 ^a	0.0026 ^a	0.0037 ^b	0.002	0.027
ΣSaturated fatty acids**	11.672 ^a	13.312 ^c	12.740 ^b	0.091	0.003
ΣMono unsaturated fatty acids	9.526 ^a	12.121 ^b	11.789 ^b	0.112	0.001
ΣPoly unsaturated fatty acids***	29.979 ^a	38.841 ^c	35.537 ^b	0.172	0.000
ΣTrans fatty acids**	0.223 ^a	0.274 ^b	0.204 ^a	0.004	0.002
¹ Σn-3 fatty acids***	14.400 ^a	21.725 ^b	21.247 ^b	0.148	0.000
² Σn-6 fatty acids***	15.519 ^b	17.059 ^c	14.236 ^a	0.036	0.000

¹n-3 FA: C18:3n-3 + C20:3n-6 + C20:5n-3 + C22:6n-3, ²n-6 FA: C18:2n-6 + C18:3n-6 + C20:4n-6 + C20:2n-6 + C20:3n-6 + C22:2n-6; LSO- Linseed oil; SEM- Standard error mean; Figures with different superscripts in a row differ significantly, *** ($P<0.001$), ** ($P<0.01$), * ($P<0.05$).

reported by Wang *et al.* (2009) and Morsy *et al.* (2015) who observed no increase or decrease in DMI and its digestibility with the inclusion of various oil sources in the diet of animals. The comparable DMI and DM digestibility among different groups could be due to lower levels of plant oils in experimental diets.

Supplementation of linseed and chia oils in diet of lactating goats influenced selective rumen parameters. Result showed that the production of acetate and butyrate in LSO group and ammoniacal-N concentration in Chia group were higher ($P<0.05$) than control group. While, total protozoa count in LSO and Chia group was comparable, but, lower ($P<0.001$) in comparison to control group. Additionally, the count of holotrichs reported highest ($P<0.01$) in group LSO as compared to all other groups. The count of entodionomorphs was found to be lower in LSO and Chia groups as compared to control group with the lowest ($P<0.01$) count in LSO group. These findings are in line with that of Abulfatah *et al.* (2016), who reported that dietary inclusion of linseed resulted in reduction of protozoal population significantly ($P<0.001$) in goat rumen. Recently, Szczechowiak *et al.* (2016), also observed significant ($P<0.05$) increase in ruminal NH_3 on addition of fish-soybean oil blend to the dairy cows which supports present findings. In contrary to above findings Kholif *et al.* (2015) obtained lower ruminal NH_3 on supplementation of crushed linseed or linseed oil in goats. The reduction in

Table 2. Fatty acid profile of feedstuffs and oils

Parameter	Fodder FA mg/g	Concentrate FA mg/g	Linseed oil, FA, mg/g	Chia oil, FA, mg/g
	DM	DM	oil	oil
C14:0	0.187	0.098	0.500	0.600
C18:0	0.676	0.913	57.800	39.500
C18:1n-9	0.875	13.511	194.800	229.800
C18:2n-6	5.379	18.313	125.700	0.400
C18:3n-6	0.009	0.272	4.800	1.900
C18:3n-3	15.918	0.659	535.800	609.300
C20:4n-6	0.067	0.025	ND	0.100
ΣSaturated fatty acids	7.279	9.247	132.200	155.600
ΣMonounsaturated fatty acids	1.735	13.855	196.500	232.100
ΣPolyunsaturated fatty acids	21.539	19.486	667.400	612.300
ΣTrans fatty acids	0.223	0.051	3.900	ND
¹ n- 3 fatty acids	16.037	0.824	536.900	609.600
² n- 6 fatty acids	5.468	18.611	130.500	2.700

¹n-3 FA: C18:3n-3 + C20:3n-6 + C20:5n-3 + C22:6n-3, ²n-6 FA: C18:2n-6 + C18:3n-6 + C20:4n-6 + C20:2n-6 + C20:3n-6 + C22:2n-6, ND-Not detectable.

Table 4. Effect of feeding n-3 FA rich plant oils on DM intake, digestibility, rumen fermentation, ruminal protozoa and blood glucose

Parameter	Diet			SEM	P value
	Control	LSO	Chia oil		
Dry matter intake, kg/d	1.447	1.418	1.324	0.062	0.915
DM digestibility, %	69.71	70.69	63.54	0.464	0.100
Ruminal fermentation					
pH	6.49	6.35	6.45	0.031	0.356
Total volatile fatty acids, mM/dl	5.81	6.81	5.91	0.156	0.080
Individual volatile fatty acids, mM/dl					
Acetate*	3.68 ^a	4.42 ^b	3.69 ^a	0.086	0.029
Propionate	1.34	1.53	1.43	0.050	0.500
Butyrate*	0.42 ^{ab}	0.49 ^b	0.37 ^a	0.013	0.016
Acetate: Propionate ratio	2.76	2.90	2.56	0.091	0.321
Ammonia-N, mg/dl*	36 ^a	46 ^{ab}	61 ^b	4.604	0.018
Protozoal population in the rumen, $\times 10^5$					
Total protozoa***	5.05 ^c	3.05 ^b	3.34 ^b	0.097	0.000
Holotrichs***	0.55 ^b	1.17 ^c	0.57 ^b	0.05	0.000
Entodionomorphs***	4.50 ^c	1.88 ^a	2.77 ^b	0.110	0.000
Blood glucose, mg/dl	44.71	51.31	45.64	1.785	0.087

LSO- Linseed oil; SEM- Standard error mean; Figures with different superscripts in a row differ significantly, * (P<0.05), *** (P<0.001).

protozoa count might lead to higher ruminal NH₃ concentration due to low utilization of NH₃ by the protozoa (Castagnino *et al.* 2015). The decrease in protozoa count was more in LSO group but NH₃ concentration was found higher in Chia oil fed group. This was due to higher entodionomorphs count in Chia oil fed group which exhibited more predatory activity than holotrichs (Belanche *et al.* 2012 and 2015). However, in present study instead of higher (P<0.001) total protozoal and entodionomorphs count, control group has lowest NH₃ concentration, it could be explained on the grounds of inhibitory effect of oil supplementation on growth of cellulolytic bacteria in the rumen (Maia *et al.* 2007). Higher population of cellulolytic bacteria in no oil supplementing control group (Szczechowiak *et al.* 2016) utilized more NH₃ as substrate for synthesis of proteins (Correddu *et al.* 2015) led to decrease in NH₃ concentration in comparison to oil fed groups.

Fat corrected milk yield, milk fat, lactose, solid not fat (SNF) and milk efficiency (Table 5) were remained at par (p>0.05) among all the animals in different groups. However, all these parameters showed numerically higher values in goats fed Linseed oil in group LSO followed by Chia group and then control group. These results are in agreement with the study of Kholif *et al.* (2011) and Morsy *et al.* (2015). This could be due to increased total VFA in rumen liquor led to improvement in blood glucose in LSO supplemented group, which in turn, translated into milk production. Additionally, in ruminants VFA account for 60–70% of metabolizable energy supply and are mainly required for milk production (Armentano 1992, Seymour

Table 5. Effect of feeding n-3 FA rich plant oils on milk production and its composition

Parameter	Diet			SEM	P value
	Control	LSO	Chia oil		
Milk yield, ml/d	970.00	1176.67	1050.00	129.0	0.939
¹ FCM, ml/d	1019.00	1350.00	1197.00	286.0	0.165
Milk Composition, %					
Fat	4.98	5.19	4.98	0.255	0.900
Protein	3.26	3.29	3.31	0.114	0.159
Lactose	4.42	4.52	4.44	0.052	0.545
Solids not fat	10.00	10.38	10.16	0.617	0.978
² Milk efficiency	0.67	0.83	0.79	0.178	0.620

¹Fat corrected milk; 4% FCM=0.4×(L of milk)+15(kg of fat)

²Milk yield (kg/d)/DM intake (kg); LSO- Linseed oil; SEM- Standard error mean.

et al. 2005). The other explanation for higher milk yield is that the protozoa are involved in methanogenesis and supplementation of diet with omega 3 FA rich oils significantly (P<0.001) reduced the protozoal population in experimental goats in comparison to control group. Consequently decrease in protozoa lowers methane production (Hegarty 1999), which spares energy that might have led to improved milk production in oil fed groups.

In contrast, Ayerza and Coates (2006) observed decrease in milk production on feeding of Chia seeds to Holstein cows. The higher milk fat in LSO supplemented goats might be due to slightly increased ruminal acetate proportion. Gargouri *et al.* (2006) in sheep and Morsy *et al.* (2015) in goats reported an increase in milk fat on supplementation of omega-3 FA source. Moreover, increased lactose content with improved feed efficiency (milk yield/DMI) was obtained as a result of LSO or Chia oil addition to goat diets, however the differences were statistically non-significant. In present study, better utilization of nutrients, biochemical changes in the rumen and favourable blood profile were responsible for higher milk production or fat corrected milk yield in animals supplemented with LSO.

The concentration of short chain fatty acids (SFA; C4:0, C8:0, C10:0) and MUFA in goat milk also remained (P>0.05) comparable among all treatment groups (Table 6). However, there was numerically decrease in myristic acid and palmitic acids in groups supplemented with Chia and Linseed oil. Earlier studies by Luna (2008), Jozwik *et al.* (2010), Beyero *et al.* (2014), Morsy *et al.* (2015) and Schettino *et al.* (2017) are in agreement with the above findings. The reduction of medium chain fatty acids could be due to the fact that they principally synthesized de novo in the mammary gland and the trans FA produced in the rumen may inhibit the synthesis of FA (Chilliard *et al.* 2001, Bernard *et al.* 2005). This result may be in the interest of human health as high proportions of these FA raise the level of cholesterol and are associated with human atherosclerosis as well as with coronary diseases (Williams, 2000).

Linoleic acid presented highest concentration of PUFA,

Table 6. Effect of feeding n-3 FA rich plant oils on fatty acid profile of goat milk (% of FA)

Fatty acid	Diet			SEM	P value
	Control	LSO	Chia oil		
C4:0	0.600	0.116	0.817	0.099	0.063
C6:0	0.637	0.977	1.22	0.115	0.057
C8:0	2.287	2.843	2.767	0.138	0.297
C10:0	10.87	11.407	9.607	0.360	0.425
C11:0	0.058	0.057	0.043	0.004	0.666
C12:0	4.213	4.020	3.327	0.135	0.462
C13:0	0.057	0.057	0.047	0.003	0.194
C14:0	10.253	9.630	8.303	0.208	0.441
C15:0*	0.997 ^b	0.900 ^{ab}	0.720 ^a	0.027	0.026
C16:0	31.06	28.32	25.87	0.611	0.140
C17:0	0.920	0.533	0.590	0.062	0.101
C18:0	13.687	16.497	14.573	0.556	0.068
C20:0	0.017	0.013	0.040	0.004	0.399
C21:0	0.103	0.083	0.090	0.004	0.072
C22:0***	0.157 ^b	0.133 ^b	0.113 ^b	0.009	0.000
C23:0***	0.016 ^a	0.040 ^c	0.023 ^b	0.007	0.001
C24:0*	0.020 ^{ab}	0.000 ^a	0.080 ^b	0.019	0.049
C14:1	0.317	0.320	0.223	0.016	0.107
C15:1	0.000	0.003	0.000	0.001	0.441
C16:1	0.617	0.487	0.730	0.039	0.242
C17:1	0.180	0.120	0.360	0.026	0.056
C18:1n-9	19.01	18.37	24.92	1.067	0.166
C20:1n-9***	0.043 ^a	0.050 ^a	0.050 ^a	0.007	0.000
C22:1n-9	0.070	0.233	0.017	0.019	0.640
C24:1n-9*	0.030 ^b	0.020 ^a	0.013 ^a	0.002	0.045
C18:2n-6	1.85	1.99	2.35	0.092	0.303
C18:3n-6	0.070	0.213	0.237	0.033	0.123
C18:3n-3*	0.660 ^a	1.160 ^b	0.740 ^a	0.057	0.048
C20:4n-6	0.160	0.160	0.257	0.057	0.076
C20:2n-6***	0.070 ^b	0.087 ^b	0.047 ^a	0.010	0.000
C20:3n-6	0.037	0.010	0.043	0.023	0.767
C20:3n-3*	0.103 ^b	0.083 ^{ab}	0.063 ^a	0.012	0.026
C22:2n-6	0.083	0.057	0.040	0.004	0.300
C20:5n-3*	0.030 ^a	0.06 ^b	0.03 ^a	0.011	0.025
C22:6n-3	0.033	0.0433	0.033	0.003	0.330
trans-18:1	0.810	0.663	1.433	0.161	0.478
trans-18:2n-6**	0.160 ^a	0.457 ^{ab}	1.933 ^{bc}	0.308	0.009
ΣSaturated fatty acids	75.673	75.627	68.326	1.078	0.111
ΣMono unsaturated fatty acids	20.260	19.390	26.3167	1.099	0.181
ΣPoly unsaturated fatty acids	3.096	3.863	3.840	0.003	0.318
ΣTrans fatty acids	0.970	1.120	1.626	0.034	0.067
¹ ΣOmega 3 fatty acid (n-3)*	0.72 ^a	1.26 ^b	0.95 ^{ab}	0.100	0.049
² ΣOmega 6 fatty acid (n-6)	2.37	2.60	3.05	0.108	0.082
ΣEPA+DHA*	0.063 ^a	0.10 ^b	0.063 ^a	0.009	0.044
n-6/n-3**	3.38 ^b	2.06 ^a	3.18 ^b	0.188	0.004
³ Desaturase index	0.034	0.030	0.031	0.003	0.837

¹n-3 FA: C18:3n-3 + C20:3n-6 + C20:5n-3 + C22:6n-3;
²n-6 FA: C18:2n-6 + C18:3n-6 + C20:4n-6 + C20:2n-6 + C20:3n-6 + C22:2n-6; ³Desaturase index C14:1/C14:0; LSO, Linseed oil; SEM- Standard error mean. Figures with different superscripts in a row differ significantly, *** (P<0.001), ** (P<0.01), * (P<0.05).

with no differences (P>0.05) among different treatment groups. The concentration of α-linolenic acid (C18:3n3) was increased from 0.66 g/100 g fat (control) to 1.16 g/100 g fat (P<0.05) in LSO group, while in Chia (0.74 g/100 g fat) group it remained at par with control group. Similarly, trans FA linolelaidic acid (trans-18:2n-6) was higher in Chia group as compared to control group, while it remained comparable to LSO group. Since, PUFA are not synthesized by ruminants, so their concentration in milk depends upon the rumen biohydrogenation and amount of PUFA absorbed from the intestine. Addition of Linseed oil to the diet of lactating goats improved EPA+DHA proportion in LSO group over control only. However, total n-3 FA were found to be higher by 75.0 and 31.9% in groups LSO and Chia, respectively as compared to control group in the milk fat (P<0.05).

Higher dietary concentration of total n-3 FA led to decrease in ratio of n-6/n-3 FA in the milk fat of goats fed Linseed and Chia oil. The results are in line with those of Morsy *et al.* (2015) who also reported reduction in the ratio of n-6/n-3 FA in milk fat on feeding of 50 g/head/d crushed linseed or 20 ml/head/d linseed oil to the dairy goats. Moreover, there was only numerically decrease in desaturation index (C14:1/C14:0) from 0.034 (control) to 0.030 (LSO) on supplementation of Linseed oil. Schettino *et al.* (2017) also observed that feeding of Chia seed had no effect on enzyme activity and this might be due to the release of the lipid from oil source or bio-hydrogenation of PUFA in the rumen.

It could be concluded that dietary inclusion of LSO or Chia oil (@ 1% of DM intake had no effect on DM intake, digestibility of DM, ruminal pH or total volatile fatty acid production in dairy goats. Additionally, the supplementation of plant oils did not alter milk yield or composition but markedly influenced the fatty acid profile of milk fat. Inclusion of LSO and Chia oil in diet of goats increased n-3 FA concentration by 75 and 31.9%, respectively along with improved n-6/n-3 ratio and desaturase index which make the milk healthier for the human consumption. However, it can be concluded that milk fatty acid profile can be modified by supplementing Linseed oil or Chia oil, but overall, linseed oil had an edge over Chia oil in improving the fermentation of feed and milk fat quality. Therefore, Chia oil is not as effective as Linseed oil under tropical climate thus rejecting our hypothesis.

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