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Effect of dietary inclusion of vegetable oils on nutrient utilization and ruminal fermentation in Surti goats

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In India, dairy goat farming is gaining considerable attention amongst small and marginal farmers due to low input and profitable returns. Use of dietary fat has received significant interest due to its high caloric value (Adeyemi *et al.* 2015) and its ability to modify fatty acid composition of ruminant's products, which are rich in CLA, n-3 and n-6 fatty acids (Bouattour *et al.* 2008). Vegetable fat supplements are usually more effective in the form of free oil than seeds or cakes at increasing the milk FA content (Nudda *et al.* 2014). However, due to extensive biohydrogenation of unsaturated lipids in the rumen (Harfoot and Hazlewood 1997) and their negative effects on fibre digestion, higher level of inclusion of dietary oils in ration is limited. Rumen protected fats are good alternative but expensive (Dewhurst *et al.* 2003) and may not be easily available for small farmers. Thus, supplementation of ration with low cost and easily available non-inert fats would be more feasible and logical. Further, PUFA rich oils like soybean oil (Bouattour *et al.* 2008, Almeida *et al.* 2019) and rice bran oil (Maia *et al.* 2006) supplementation in goats to alter final ruminant products fatty acid composition in western countries has been studied recently. However, to the best of our knowledge, there is scanty information about supplementation of PUFA rich oils in milch goat breed of India. Therefore present experiment was planned to study the effects of soybean oil or rice bran oil supplementation on nutrient utilization and ruminal fermentation in Surti goats.

The present study was carried out at Livestock Research Station (LRS), Navsari Agricultural University, Navsari, Gujarat, India. Multiparous lactating Surti goats (24) were randomly distributed into four groups on the basis of live body weight (28.10±1.04 kg), parity (4.47±0.47) and previous lactation yield (133.39±5.00 kg) for period of 150 days after kidding. Treatment groups were classified as basal diet supplemented with no oil (CON), 3% of DMI of soybean oil (SBO), 3% of DMI of rice bran oil (RBO) and equi-proportional blend of 1.5% of DMI of soybean oil and rice bran oil each (SRBO). Basal diet consisted of compound concentrate mixture, green jowar and pigeon pea straws. The additives were mixed with concentrate mixture before morning feeding at 08:30 h daily. Compound concentrate mixture was fed at 08:30 h, green sorghum at 10:00 h and 16:00 h while pigeon pea straws were fed *ad lib.* during night hours. Experimental animals were individually fed for 150 days according to ICAR feeding standard (2013).

Body weight and dry matter intake was recorded at fortnight interval throughout experimental period. A metabolism trial of seven days was conducted at mid experiment to assess nutrient utilization efficiency (digestibility) where, all the animals were shifted to the metabolic cages, having facilities for separate urine and faeces collection. Daily feed intake, left over and excretion of faeces and urine were recorded and representative samples were collected for further analysis. Samples of feed ingredient were analysed for proximate composition according to the methods of AOAC (2005) and fibre fractions by Van soest *et al*. (1991). Rumen liquor samples were collected from each experimental animal through stomach tube in morning hours after feeding of concentrates at 15, 75 and 150 days of experiment. Rumen samples were filtered through muslin cloth and *p*H was immediately measured with digital *p*H meter. Strained rumen liquor (SRL) of 50 ml was collected in the airtight plastic bottle container and kept at –20°C until laboratory analysis. Total volatile fatty acids (TVFA) production was determined by steam distillation process using Markham micro-distillation apparatus as reported by Barnet and Ried (1956). Ruminal ammonia nitrogen, total nitrogen, TCA precipitable nitrogen was estimated according to Kjeldahl method (AOAC 2005) while soluble nitrogen was determined by difference between total nitrogen and TCA precipitable nitrogen.

Data for ruminal parameters were analysed by using the PROC MIXED procedure of SAS with repeated measures (version 9.3; SAS Institute Inc., Cary, NC) using Tukey's HSD (honestly significant difference) multiple comparison test and following statistical model was used.

$$Y_{ijk} = \mu + A_k + D_i + T_j + (D_i \times T_j) + e_{ijk}$$

where, Y_{ijk}, Dependent variable; μ, overall mean; A_k,

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Table 1. Proximate composition of experimental feeds (% DM basis)

Attribute	Concentrate mixture	Pigeonpea straws	Green jowar
Dry matter	89.20	90.25	22.20
Organic matter	91.27	90.70	83.40
Crude protein	19.30	09.41	04.00
Ether extract	04.11	01.26	01.89
Neutral detergent fibre	22.96	74.48	58.35
Acid detergent fibre	15.31	57.40	42.60
Crude fibre	06.90	29.70	29.20
Nitrogen free extract	60.96	50.33	48.31
Hemicellulose	07.65	17.08	15.75
Total carbohydrate	67.86	80.03	77.51
Lignin	03.48	04.75	10.73
Ash	08.73	09.30	16.60
Calcium	01.49	01.68	00.39
Phosphorus	01.23	00.28	00.20

Random effect of animals; D_i, Fixed effect of diet; T_j, Fixed effect of time; e_{ijk}, Residual error.

The statistical model contained fixed effects of treatment and experimental period and their interactions, random effects of animal and residual error. Parameters related to digestibility of feed and nitrogen balance were analysed by one-way ANOVA using tukey's HSD. Differences were declared significant at P<0.05, with values of P<0.10 being interpreted as a trend towards significance.

Proximate composition of experimental feeds offered is presented in Table 1. The roughage: concentrate ratio was tried to maintain at 70 : 30 during whole experimental period. The diet was isonitorgenous but due to addition of oil it was not isocaloric (Bouattor *et al.* 2008, Adeyemi *et al.* 2015).

Average initial and final body weight (kg) of treatment groups was similar (P>0.05) amongst treatment groups. Numerically, increased body weight with time can be correlated with increased DMI and metabolizable energy intake (Table 2) and suggests that all animals were under positive energy and nitrogen balance to meet the nutrient requirements for milk production. Although effect of diet on body weight was not reflected in oil supplemented groups, which might be due to extra available energy that might have been diverted to milk production. Dry matter intake (g/d) remained similar (P>0.05) amongst treatment groups. DMI from concentrate and roughage also remained statistically similar (P>0.05). Present findings are supported by Bouattour *et al.* (2008), Titi and Rahman (2013), Adeyemi *et al.* (2015) and Ferreira *et al.* (2018). Statistically similar DMI due to addition of unprotected oil into ration of lactating goat indicates that plant oil inclusion was in sufficient amount and oil either alone or in combination does not hamper fibre digestion. On the contrary, when Bernard *et al.* (2015) supplemented linseed and fish oil in goat and Kitessa *et al.* (2001) supplemented fish oil in sheep they reported that addition of plant origin oil or animal origin oils tends to depress DM intake in small ruminants.

Nutrient intake and digestibility of CP, NDF and ADF for all the treatment groups remained statistically (P>0.05) similar (Table 3). Statistically similar (P>0.05) digestible crude protein intake might be due to isonitrogenous diet and further experimental groups showed non-significant body weight change during the experiments which indicates that nitrogen metabolism was not affected with diet. Almeida *et al.* (2019) found similar protein and fibre digestibility when goats were supplemented with soybean, linseed or fish oil. Non significant digestibility of fibre fractions indicates that ruminal fibre digestion was not

Table 2. Effect of vegetable oil on nutrient intake and apparent digestibility of experimental animals

Attribute	CON	SBO	RBO	SRBO	SEM	P value
Nutrient Intake (g/d)						
Initial body weight (kg)	27.42	28.48	27.97	28.52	0.97	0.980
Final body weight (kg)	29.48	30.15	29.75	30.97	0.93	0.956
Dry matter	975.31	1016.27	1008.91	994.54	28.42	0.751
Concentrate	350.21	354.71	350.07	367.57	5.83	0.144
Dry fodder	511.97	576.59	516.71	542.08	16.72	0.622
Green fodder	256.53	252.99	263.01	222.99	11.19	0.625
Crude protein	118.12	124.92	116.82	122.96	2.27	0.568
Ether extract	23.41^{b}	58.27^{a}	56.58^{a}	54.01^{a}	3.08	<0.001
Neutral detergent fibre	652.63	699.72	670.21	659.47	15.97	0.762
Acid detergent fibre	490.44	526.72	504.32	496.10	12.11	0.755
DCP	84.85	88.83	84.19	85.05	1.82	0.823
TDN	678.46^{b}	778.97^{a}	771.68^{a}	721.44^{ab}	21.73	<0.049
Apparent Digestibility (%)						
Dry matter	64.92	64.08	66.10	61.03	1.53	0.708
Crude protein	71.91	71.14	72.23	69.45	1.19	0.862
Ether extract	74.31^{b}	93.18^{a}	93.60^{a}	92.38^{a}	1.81	<0.001
Neutral detergent fibre	67.24	65.79	68.22	63.70	1.40	0.715
Acid detergent fibre	65.83	65.61	66.90	62.06	1.45	0.693

^{abc}, Means with different superscript in a row differ significantly (P<0.05).

Table 3. Effect of vegetable oils on nitrogen balance (g/d) of experimental animals

Attribute	CON	SBO	RBO	SRBO	SEM	P value
N in feed	18.90	19.99	18.69	19.67	0.36	0.569
N in faeces	5.32	5.78	5.22	6.06	0.29	0.734
N in urine	6.42	6.14	5.45	6.79	0.31	0.070
N in milk	3.18	4.00	4.17	2.73	0.35	0.435
N-balance	3.98	4.07	3.85	4.09	0.40	0.863
N-retained % of N Intake	21.07	20.36	20.60	20.77	1.54	0.980

hampered by addition of oil and level of oil inclusion was adequate for optimal ruminal environment. Present findings were further, supported by ruminal *p*H of experimental animals which was within range (Table 4). In contrast, Lunsin *et al*. (2012) found decreased fibre fractions digestibility with increasing level of rice bran oil in cattle.

However, EE intake and digestibility was significantly (P<0.01) higher in all three oils supplemented groups as compared to control but remained at par (P>0.05) between oil supplemented groups. Increased EE digestibility can be attributed to the fact that non-fatty acids lipids in the diet are relatively less digestible and diluting this fraction with more easily digestible fatty acids, increases the digestibility of EE fraction (Li *et al.* 2009, Adeyemi *et al.* 2015). In contrast, Kholif *et al.* (2018) found non-significant ether extract digestibility when goats were supplemented with flaxseed oil and seeds. Due to increased EE intake with oils supplementation, TDN intake was also significantly (P<0.05) higher in SBO, RBO and SRBO as compared to CON.

Protein metabolism and turnover rate can be effectively studied by estimation of nitrogen balance. Nitrogen intake from feed for experimental groups remained at par (P<0.05). Nitrogen excretion from faeces, urine and milk and nitrogen retained per cent of intake also remained statistically (P>0.05) similar (Table 3). Non significant DMI and final body weight indicates that protein metabolism was not hampered by oil supplementation. Further, nitrogen balance also indicated that all the animals were on positive nitrogen balance throughout experimental period. Adeyemi *et al*. (2016) also found non-significant nitrogen balance in lactating goat supplemented with blend of canola and palm oil.

Ruminal parameters like *p*H, ammonia nitrogen, total nitrogen and its fraction were at par (P<0.05) amongst treatments groups and within normal range (Adeyemi *et al.* 2015). Ruminal *p*H was affected by neither diet nor sampling time and was ideal for fibre digestion in rumen (Orskov 1994). Further, reduced fibre digestibility and microbial synthesis (De veth and Kolver 2001) have been observed when rumen *p*H falls below 6.2. Similarly, ADF and NDF digestibility also suggest that oils supplementation did not affect the fibre digesting bacterial population hence, fibre degradability. Ruminal TVFA (mmol/L) was significantly (P<0.05) increased with dietary inclusion of soybean oils and/or rice bran oil as compared to control. However, time had no effect on TVFA concentration. Total VFA concentration in the rumen depends on nutrient digestibility, rumen *p*H, passage rate, rate of absorption as well as the microbial population and their activities in the rumen. Significantly (P<0.01) higher concentrations of TVFA with SBO, RBO and SRBO indicates more efficient anaerobic fermentation (Morsy *et al.* 2015).

Ruminal ammonia-N did not differ (P>0.05) significantly with both diet and time. In present study, concentration of rumen ammonia-N was above the minimum concentrations required (≥5 mg/dL) for rumen microbial growth and for optimum fibre degradation in the rumen (Morsy *et al.* 2015). Non significant (P>0.05) ammonia-N concentrations in the treatment groups can be considered as an indicator of optimum ruminal fermentation rate and microbial protein synthesis. Earlier studies have reported an increase (Messana *et al.* 2013), a decrease (Morsy *et al.* 2015) or no variation (Adeyemi *et al.* 2015) in ammonia-N concentration following lipid supplementation. However, an extensive review by Doreau and Ferlay (1995) suggested little or no effect of dietary lipid on ammonia-N concentration. Total N (mg/dl), TCA precipitable nitrogen and soluble nitrogen remained similar (P>0.05) amongst treatment groups and neither diet nor sampling time showed any effects on mentioned parameters.

SUMMARY

With an objective to study vegetable oils supplementation on nutrient utilization and ruminal fermentation, 24 multiparous lactating Surti goats were divided into four

Table 4. Effect of vegetable oil supplementation on ruminal fermentation of experimental animal

Parameter	CON	SBO	RBO	SRBO	SEM	P value		
						D	T	D × T
*p*H	6.44	6.49	6.41	6.45	0.04	0.645	0.688	0.207
TVFA (mmol/L)	6.26^{b}	7.06^{a}	6.85^{ab}	6.99^{ab}	0.29	<0.012	0.422	0.719
Ammonia Nitrogen (mg/dl)	12.22	12.25	12.72	12.49	0.12	0.217	0.201	0.830
Total Nitrogen (mg/dl)	76.08	76.66	75.55	76.72	2.97	0.991	0.928	0.976
TCA Nitrogen (mg/dl)	29.43	31.30	30.55	30.72	1.38	0.810	0.512	0.988
Soluble Nitrogen (mg/dl)	46.65	45.36	45.00	46.00	3.02	0.981	0.663	0.990

D, Diet; T, Time; D×T, Diet and time interaction; SEM, Standard error of mean; ^{abc}, Means with different superscript in a row differ significantly (P<0.05).

groups as basal diet supplemented with no oil (CON), 3% of DMI soybean oil (SBO), 3% of DMI of rice bran oil (RBO) and equi-proportional blend of 1.5% of DMI of soybean oil and rice bran oil each (SRBO). DM, CP, NDF and ADF intake (g/d) and their digestibility (%) remained statistically similar amongst dietary treatments groups, except EE which was significantly improved in all the oil supplemented groups as compared to control. Nitrogen balance of experimental groups remained unaffected and all the animals were under positive nitrogen balance. Rumen metabolites like *p*H and total nitrogen and its fractions (ammonia N, TCA precipitable N and soluble N) remained similar amongst treatment except TVFA. Thus, soybean oils and/or rice bran oils at level of 3% of DMI can be effectively incorporated in ration of lactating Surti goats without affecting nutrient utilization and rumen fermentation.

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