Effects of Soybean and Rice Bran Oil Supplementation on Nutrient Utilization, Lactation Performance, Milk Fatty Acid Profile and Ruminal Fermentation in Surti Goats

Ajay Prahladbhai Raval (dr.ajayraval@gmail.com)
Navsari Agricultural University https://orcid.org/0000-0002-3417-5648
Vipul R Patel
Navsari Agricultural University
Lalitchandra M Sorathiya
Kamdhenu University
Jignesh K Movalia
Navsari Agricultural University

Research Article

Keywords: Milk fatty acid, Soybean oil, Rice bran oil, Surti goat

Posted Date: June 21st, 2021

DOI: https://doi.org/10.21203/rs.3.rs-590075/v1

Effects of soybean and rice bran oil supplementation on nutrient utilization, lactation performance, milk fatty acid profile and ruminal fermentation in Surti goats

A. P. Raval[*1], V. R. Patel[1], L. M. Sorathiya[2] and J. K. Movaliya[1]

1 Department of Animal Nutrition, College of Veterinary Science and A.H., Navsari Agricultural University, Navsari, Gujarat- 396450, India.

2 Post- Graduate Institute of Veterinary Education & Research (PGIVER), Kamdhenu University, Himmatnagar, Gujarat- 383001, India.

***Corresponding Author: dr.ajayraval@gmail.com (ORCID:0000-0002-3417-5648)**

Short Title: Soybean and rice bran oil supplementation in Surti goats

Abstract

A study was conducted to observe the effect of soybean and rice bran oil supplementation on nutrient utilization, lactation performance and ruminal fermentation in Surti goats. Twenty-four multiparous lactating Surti does were distributed into four homogenous groups for entire lactation of 150 days. Control group (CON) was offered a basal diet consisting of compound concentrate mixture, green jowar and pigeon pea straws without any oil supplementation, while other treatment groups were additionally supplemented with soybean oil @ 3% of DMI (SBO), rice bran oil @ 3% of DMI (RBO) and equi-propotional blend of soybean oil and rice bran oil @ 3.0 % of DMI (SRBO). DM, CP, NDF and ADF intake (g/d) and digestibility (%) remained statistically ($p>0.05$) similar amongst dietary treatments groups. EE intake (g/d) and digestibility (%) was significantly ($p<0.01$) improved in all three oils supplemented groups as compared to control but values between oils supplemented groups remained at par ($p>0.05$). Nitrogen balance of experimental groups remained unaffected ($p>0.05$) and all the animals were under positive nitrogen balance. Milk yield (kg/d), milk fat, SNF, protein, lactose, FCM and ECM yields (g/d) were significantly ($p<0.05$) increased in oils supplemented groups as compared to control. Feed efficiency in terms of MY/DMI and FCM/DMI significantly ($p<0.05$) improved in SBO, RBO and SRBO as compared to CON. Soybean and rice bran oil supplementation either alone or in combination significantly reduced ($p<0.05$) SCFA, MCFA, SFA with increased LCFA and PUFA in milk. However, values between oils supplemented groups remained at par ($p>0.05$). Oil supplementation increased ($p<0.001$) oleic acid (C18:1 n-9) and linoleic acid (C18:2 n-6) in SBO, RBO and SRBO as compared to CON while, linolenic acid (C18:3 n-9) remained non significant amongst treatments. Lipid quality indices (LQI) like atherogenicity index, thrombogenicity index and hypocholesterolaemic/hypercholesterolaemic (h/H) index were significantly improved in all the oils supplemented groups as compared to control. Rumen pH, total

nitrogen and its fractions (ammonia N, TCA precipitable N and soluble N) remained similar ($p>0.05$) amongst treatment except TVFA. Thus, supplementation of soybean oil and rice bran oil either alone or in combination in lactating goat can be effectively used to improve both nutritional quantity and quality of milk.

Key words: Milk fatty acid, Soybean oil, Rice bran oil and Surti goat

Introduction

With highest goat population in world, dairy goat farming is gaining importance in Indian sub continent, which provides food and nutritional security to the millions of small and marginal farmers (Haenlein 2004). Goat milk and milk products consumption is considered beneficial for humans due to its technological advantage with regards to smaller size of fat globules, lower amount of casein and higher mineral compounds over cow milk (Attaie and Richter 2000; Gomes et al. 2013). Goat milk production and composition, especially (Fatty acid profile and flavour) is a genetic trait, but it can be effectively altered by the dietary supplementation with lipids (Nudda et al. 2006). During last decade, there is an increased interest in researchers to reduce saturated fatty acids and enrich product with beneficial polyunsaturated fatty acids (PUFA) or conjugated linoleic acid (CLA), which could offer potential health benefits to consumers (Bouattour et al. 2008). Fatty acid content in goat milk is affected by the fat content, type of predominant fat and physical form of the dietary fat supplement (Nudda et al. 2014). Vegetable fat supplements are usually more effective in the form of free oil than in the form of seeds at increasing the milk FA content (Nudda et al. 2014). Plant oils from different oilseeds sources have different FA compositions and accordingly exert different effects on milk FA profile (Gómez-Cortés et al. 2008). Feeding PUFA rich vegetable oils like soybean oil (Almieda et al. 2019; Li et al. 2009) and rice bran oil (Maia et al. 2006) has been shown to affect milk yield and composition. However, to the best of our knowledge, there is meager information about response of vegetable oil

supplementation to dairy goats in Indian tropical conditions. Therefore, present experiment was planned with hypothesis that, supplementing soybean oil or rice bran oil would have beneficial effects on production performance and milk fatty acid composition.

Materials and Methods

Animals, feeding and experimental design

The feeding trial was carried out at Livestock Research Station (LRS), Navsari Agricultural University, Navsari, Gujarat, India. Twenty-four multiparous lactating Surti goats were randomly distributed into four homogenous groups on the basis of live body weight (28.10±1.04 kg), parity (4.47±0.47) and previous standard lactation yield (133.39±5.00 kg/150d) up to entire lactation of 150 days. Control group (CON) was offered basal diet without any oil supplementation, while other treatment groups were additionally supplemented with soybean oil @ 3% of DMI (SBO), rice bran oil @ 3% of DMI (RBO) and equi-propotional blend of soybean oil and rice bran oil @ 3.0 % of DMI (SRBO). Basal diet consisted of compound concentrate mixture, green jowar and pigeon pea straws. Experimental animals were individually fed during entire experiment according to ICAR feeding standard (2013). Compound concentrate mixture mixed with oil was fed once daily at 08.30 h, green sorghum at 10.00 h and 16.00 h while pigeon pea straws were fed *ad libitum* during night hours. *Ad libitum* drinking water was available at all the time during experiment. At mid of experiment a metabolism trial of seven days was conducted to assess the nutrient utilization efficiency (digestibility). During metabolism trial, all the animals were shifted to the metabolic cages, having facilities for separate urine and faeces collection. Daily feed intake and output of faeces and urine was recorded and representative samples were collected for further processing and analysis. Samples were analysed for proximate composition (AOAC 2005), fibre fractions (Van soest et al. 1991) and fatty acid analysis (O'fallon et al. 2007).

Sampling and analysis of milk composition

Goats were hand milked twice a day and fortnightly milk samples were collected for chemical composition i.e. fat, solid not fat (SNF), protein and lactose using infrared spectrophotometry (MilkoScan™ FT1 120). Samples for milk fatty acid were collected in separate airtight plastic bottle container for each animal and stored at −20 °C (ultra low temperature freezer) until laboratory analysis.

FA analysis

Fatty acid were analysed as per direct transesterification method of O'Fallon et al. (2007). FAME was prepared by base-catalysed methanolysis of glycerides (KOH in methanol) according to international standards (ISO-IDF 2002) and stored in vial at -20°C for further analysis. FAME was analysed on gas chromatography mass spectrometer (GCMS-QP 2010 Plus) equipped with an auto sampler injector. The FAME was separated in 60 m capillary column (60 m x 0.25mm x 20 um) film thickness with mass spectrometer. Helium was used as carries gas at a flow rate of 1 mL/min. The injector and detector temperatures were 250°C and 240°C, respectively. The temperature programme was follow as: Initial temperature held at 100°C for 5 min after sample injection, then programmed to increase at 2 °C/min to 240 °C and held there for 5 min. Sample (1uL) were injected by split injection (split ratio 50:1). The mass spectrometer was operated at source temperature 230°C; interface temperature 240°C with electronspray ionization (EI) method and scan range of 50-1000 m/z. Identification of FAME was performed from the retention time by using standards of 37 individual FAME (Supelco, Bellefonte, PA) was used to determine response factors. The peak areas in the chromatograph were calculated and normalized using response factors.

Sampling and analysis of rumen liquor

Rumen liquor samples were collected from each experimental animal by stomach tube. Collection was done two hours after morning feeding of concentrates at 15, 75 and 150 days

of experiment. Rumen liquor was filtered through four layer muslin cloth and pH was immediately measured with digital pH meter. Strained rumen liquor (SRL) of 50 ml was collected in the airtight plastic bottle container and kept at −20°C (ultra low temperature freezer) until laboratory analysis. Ruminal ammonia-N was determined according to AOAC (2005). Total volatile fatty acids (TVFA) production was determined by steam distillation process using Markham micro-distillation apparatus (Barnet and Ried 1956). Total nitrogen, TCA precipitable nitrogen was estimated according kjeldahl method (AOAC 2005) while soluble nitrogen was determined by difference between total nitrogen and TCA precipitable-nitrogen.

Statistical Analysis

Data for body weight, milk yield, milk composition and ruminal parameters of animals were analyzed 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. Following statistical model was used.

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

Y_{ijk}= Dependent variable, μ= Overall mean; A_k = 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, milk fatty acid 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.

Results and Discussion

Proximate and fatty acid composition of experimental feeds

Proximate and fatty acid composition of experimental feed offered is presented in table 1. Roughage: concentrate ratio was tried to maintain at 70:30 during whole experimental period. Experimental diet was isonitorgenous in nature but due to addition of oil it was not isocaloric (Adeyemi et al. 2015; Bouattor et al. 2008).

Table 1: Proximate and fatty acid composition of experimental composition of experimental diet (% DM basis)

Attributes	CON	SBO	RBO	SRBO
Dry matter	67.37	64.69	64.69	64.69
Organic matter	85.10	82.20	82.20	82.20
Crude Protein	12.09	11.95	11.95	11.95
Ether Extract	2.55	5.44	5.44	5.44
Neutral detergent fiber	50.35	49.82	49.82	49.82
Acid Detergent fiber	36.98	36.63	36.63	36.63
ME (MJ/kg DM)	10.36	11.08	11.07	11.07
FA composition (g/100 g FA*)*				
C10:0	0.65	0.49	0.49	0.49
C12:0	0.79	0.60	0.60	0.60
C14:0	1.27	0.98	1.05	1.01
C16:0	21.24	18.55	20.03	18.83
C16:1	0.15	0.13	0.16	0.14
C18:0	11.00	9.53	8.86	9.38
C18:1	14.77	16.63	20.02	18.69
C18:2	25.26	30.96	26.72	29.17
C18:3	9.27	8.61	8.33	8.32

C20:0	0.79	0.69	0.83	0.60
C22:0	2.24	1.79	1.77	1.79
C24:0	1.42	1.10	1.19	1.14

Nutrient intake and digestibility

Dry matter intake (DMI; g/d) was similar ($p>0.05$) amongst treatment groups with diet but significantly ($p<0.01$) affected with time. Non-significant DMI was observed when in lactating ewes when supplemented with soybean oil and sunflower oil (Titi and Rahman 2013) and with soybean oil (Bouattour et al. 2008) in goats. Statistically similar DMI with addition on unprotected oil in to ration of lactating goats indicates adequate inclusion level of plant oils and both oil either alone or in combination does not hampers the fiber digestion (Adeyemi et al. 2015). In contrary, Bernard et al. (2009) found depressed DMI with sunflower (130 g/d) and linseed oils (130 g/d) supplementation on maize silage based diet in lactating goats.

Average initial and final body weight (kg) of treatment groups was similar ($p>0.05$) amongst treatments. Numerically, increase in body weight with time would suggest that animals were under a positive energy balance and that energy and protein provided by all diets were adequate to meet the requirements for milk production (Titi and Rahman 2013). Although diet effect on body weight was not reflected, which might be due to extra available energy might have been diverted to milk production and composition (Table 4).

Nutrient intake and apparent digestibility of experimental groups is mentioned in table 2. Intakes and digestibility of DM, CP, NDF and ADF for all the treatment groups remained statistically ($p>0.05$) similar. Almieda et al. (2019) found non significant apparent digestibility with supplementation of soybean, sunflower linseed or fish oil at 5.1 % of DMI. Non significant digestibility of fiber fractions indicates that ruminal fiber digestion was not hampered by addition of oil and inclusion level of oil was adequate for optimal ruminal

163 environment (Adeyemi et al. 2015). Present findings were further, supported by ruminal pH
164 of experimental animal which was within range (Table 7). In contrast, Lunsin et al. (2012)
165 found decreased fiber fractions digestibility with increasing level of rice bran oil in cattle.

166 EE intake and digestibility was significantly ($p<0.01$) higher in all three oils
167 supplemented groups as compared to control. However, values between oils supplemented
168 groups remained at par ($p>0.05$). Increased EE digestibility can be attributed to the fact that
169 non-fatty acids lipids in the diet are relatively less digestible and diluting this fraction with
170 easily digestible fatty acids from oil, increases the digestibility of EE fraction (Adeyemi et al.
171 2015; Li et al. 2009). In contrast, when goats were supplemented with soybean, linseed and
172 fish oil (Almieda et al. 2019) and with flaxseed oil (Kholif et al. 2018) found non-significant
173 ether extract digestibility. Due to increased EE intake with oils supplementation, TDN intake
174 was also significantly ($p<0.05$) increased in SBO, RBO and SRBO as compared to CON.
175 However, TDN intake was similar amongst oils supplemented groups.

176 **Table 2: Effect of vegetable oil on nutrient intake and apparent digestibility of**
177 **experimental animals**

Attributes	CON	SBO	RBO	SRBO	SEM	P value
Nutrient Intake (g/d)						
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
Body weight (kg)	28.21	28.41	28.11	29.43	0.63	0.437
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 fiber	652.63	699.72	670.21	659.47	15.97	0.762

Acid detergent fiber	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 fiber	67.24	65.79	68.22	63.70	1.40	0.715
Acid detergent fiber	65.83	65.61	66.90	62.06	1.45	0.693

abc -Means with different superscript in a row differ significantly ($p<0.05$)

Nitrogen balance

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 as percent of intake was also remained statistically ($p>0.05$) similar (Table 3). 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.

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

Attributes	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

Milk yield and composition

Milk yield (kg/d) was significantly ($p<0.05$) increased in SBO (+25.97%), RBO (+32.46%) and SRBO (+10.38%) as compared to CON. While, amongst the oil supplemented groups, RBO found highest increase in milk production which was significantly apart from SBO and SRBO. Increased available metabolisable energy with oil supplementation might be the reason behind increased milk yield. Gómes-Cortés et al. (2008) concluded that increased milk yield was due to greater energy content of the oil supplemented diets and not by a greater DMI. Various scientists found increased milk yield with vegetable oils supplementation in goat (Bernard et al. 2009; Hassan et al. 2020; Ibrahim et al. 2020; Mele et al. 2008) and sheep (Ferreira et al. 2018; Nudda et al. 2015). In contrast to present result, Almieda et al. (2019); Bernard et al. (2015) and Bouattour et al. (2008) and found no effect of PUFA rich oil supplementation on milk yield in goats. Differing responses of milk yield to dietary fat may relate in part to the genetic potential of the goats for milk yield, the supply of energy from the basal diet and the effects of the dietary fat on DMI and nutrient partitioning (Manso et al. 2011).

Milk fat concentration and yield was increased ($p<0.01$) significantly with diet in SBO, RBO and SRBO as compared to CON but values remained unaffected with time. Many researchers found combined effect of increased milk fat concentration along with milk yield (Bernard et al. 2009; Bernard et al. 2015; Morsy et al. 2015; Li et al. 2016) while some reported only increased milk fat (Bouattour et al. 2008; Li et al. 2009) with PUFA rich oils supplementation in lactating goats. In contrast, Reyes et al. (2018) found similar milk fat and milk production with canola and soybean oil supplementation (20ml/d/goat). Neither diet nor sampling time had significant ($p>0.05$) effect on milk SNF, protein and lactose concentration.

However, milk SNF, protein and lactose yields were increased, which was highest in RBO followed by SBO, SRBO and CON. Increased milk yield and milk fat concentration was directly reflected in increased yield of milk fat, SNF, protein and lactose in oils supplemented groups as compared to control. Almieda et al. (2019) and Manso et al. (2011) found statistically similar milk protein and lactose concentration. However, ewes were supplemented with linseed (Nudda et al. 2015) found improved milk protein and lactose concentration.

Milk composition in terms of percentage is not sufficient enough to evaluate the milk quality. So various methods formulated that estimates relative energy value required to produce milk when milk yield is adjusted with amount of fat (fat corrected milk) and amount of fat, protein and lactose (energy corrected milk). The FCM, SCM and ECM yields (kg/d) were significantly ($p<0.01$) with oils supplementation but remained unaffected ($p>0.05$) by time. Titi and Rahman (2013) observed increased ECM for ewes supplemented when with soybean and sunflower oil @ 3 % of DMI. However, Bouattour et al. (2008) found non-significant ECM yield in soybean oil supplemented group as compared to control in goat. Milk energy output (MJ/d) and milk energy content (MJ/kg) was significantly ($p<0.01$) increased with oil supplementation. Feed efficiency in relation to milk yield and FCM yield was significantly ($p<0.01$) improved in SBO, RBO, and SRBO with diet and time in all three oil supplemented groups as compared to control. Increased milk production without affecting DM intake of animal reflects efficient utilization of feed. Morsy et al. (2015) also found increased feed efficiency in relation to DM in sunflower and soybean oils supplemented groups as compared to control in goats.

Table 4: Production performance of experimental Surti does supplemented with vegetable oil

Parameters	CON	SBO	RBO	SRBO	SEM	P value		
						Diet	Time	DxT

Yield								
Milk (kg/d)	0.77^{b}	0.95^{ab}	1.02^{a}	0.85^{ab}	0.06	<0.007	0.216	0.993
Fat (g/d)	28.16^{c}	47.19^{ab}	52.11^{a}	39.83^{b}	2.88	<0.001	0.322	0.959
SNF (g/d)	62.18^{b}	78.11^{ab}	80.47^{a}	66.46^{ab}	4.58	<0.012	0.110	0.987
Protein (g/d)	23.54^{b}	29.80^{ab}	33.63^{a}	25.88^{ab}	1.96	<0.002	0.638	0.947
Lactose (g/d)	31.69^{b}	40.09^{ab}	41.79^{a}	34.65^{ab}	2.54	<0.019	0.265	0.945
Total solid (g/d)	92.20^{b}	125.33^{a}	128.81^{a}	94.00^{b}	8.82	<0.002	0.171	0.974
FCM (kg/d)[1]	0.73^{c}	1.10^{ab}	1.19^{a}	0.94^{bc}	0.08	<0.001	0.291	0.978
SCM (kg/d)[2]	0.70^{c}	1.02^{ab}	1.09^{a}	0.86^{bc}	0.06	<0.001	0.204	0.972
ECM (kg/d)[3]	0.64^{c}	1.19^{ab}	1.42^{a}	0.79^{bc}	0.12	<0.001	0.265	0.885
Concentration (%)								
Fat	3.70^{b}	4.97^{a}	5.02^{a}	4.69^{a}	4.60	<0.001	0.239	0.652
SNF	8.10	8.08	7.84	7.85	7.95	0.062	0.265	0.836
Protein	3.11	3.02	3.19	3.03	3.09	0.053	0.084	0.984
Lactose	4.09	4.38	3.98	4.03	4.12	0.507	0.797	0.748
Milk energy output (MJ/d)[4]	2.15^{c}	3.17^{ab}	3.47^{a}	2.70^{bc}	0.19	<0.001	0.401	0.957
Milk energy content(MJ/kg)[5]	2.82^{c}	3.30^{ab}	3.37^{a}	3.17^{b}	0.05	<0.001	0.379	0.577
Milk efficiency								
MY/DMI	0.81^{b}	1.08^{a}	1.09^{a}	0.87^{ab}	0.07	<0.014	<0.001	0.996
FCM/DMI	0.77^{b}	1.20^{a}	1.27^{a}	0.96^{ab}	0.08	<0.001	<0.003	0.994

D- Diet; T- Time; DxT- Diet and time interaction; SEM- Standard error of mean; abc-Means with different superscript in a row differ significantly ($p<0.05$)

[1]Fat corrected milk (kg/d) = 0.4*milk (kg) + 15*fat (kg) (Tyrell and Reid 1965).

[2]Solid corrected milk (kg/d) = 12.3× fat (kg) + 6.56× SNF (kg) – 0.0752× milk yield (kg) (Tyrell and Reid 1965).

[3]Energy correct milk (kg/d) = Milk (kg/d)*[38·3*fat (g/kg) + 24·2*protein (g/kg) + 16·54*lactose (g/kg) + 20·7]/3140 (Sjaunja et al. 1991).

[4]Milk energy content (MJ/kg) = 4·184*2·204*[(41·63*fat (g/100g) + 24·13*protein (g/100g) + 21·60*lactose (g/100g)−11·72)/1000] (Tyrell and Reid 1965).

[5]Milk energy output (MJ/d) = Milk energy (MJ/kg)* milk yield (kg/d) (Morsy et al. 2018)

Milk fatty acid profile

Both the oils either alone or in combination significantly decreased ($p<0.001$) short and medium chain FA and increased ($p<0.001$) long-chain FA in the milk. Decreased concentrations of short and medium chain fatty acids (mostly *de novo* synthesized) in PUFA supplemented groups are consistent with previous studies in lactating goats (Almieda et al. 2019; Bernard et al. 2015; Pascual et al. 2019), sheep (Ferreira et al. 2018; Nudda et al. 2015) and cows (Lunsin et al. 2012). This response is might be due to supplementation of PUFA rich oils increases the concentration of CLA isomer (*trans*-10, *cis*-12), which is a powerful inhibitor of the *de novo* fatty acids synthesis in mammary gland due to the reduction of the key lipogenesis enzymes (*acetyl-CoA carboxylase* and *fatty acid synthetase*) synthesis (Palmquist et al. 2005). Short and medium chain FAs are synthesized from acetate and β-hydroxybutyrate in mammary gland. The *de novo* synthesis does formation of fatty acids of up to 16 carbons, reducing short and medium chain fatty acids content in the milk. In addition, the capric, caproic and caprylic fatty acids are responsible for the characteristic odor in the caprine milk and meat products (Ibrahim and Soryal 2014), which may create some consumers resistance for meat, milk and their derivatives (Chilliard et al. 2003). Therefore, the reduction of SCFA and MCFA may be important to increase acceptability of these products by consumers. Furthermore, MCFA reduction is desirable because the lauric, myristic and palmitic fatty acids are associated with cardiovascular diseases development (Ferreira et al. 2018). Moreover, the addition of both PUFA rich oils alone or in combination decreased ($p<0.05$) saturated FA concentrations and increased ($p<0.001$) unsaturated FA concentrations and MUFA and PUFA contents in the milk. Stearic (C18:0), oleic (C18:1 n-9)

and linoleic acids (C18:2 n-6) were increased, whereas linolenic acid (C18:3 n-3) was similar in soybean oil and/or rice bran oil supplementation with comparison to control.

The increases in C18:0 and C18:1 fatty acid may be a consequence of higher intakes of these FA in the diet along with biohydrogenation process of unsaturated C18 FA in the rumen. Oleic acid can also be increased by the action of mammary Δ^9desaturase on C18:0. Grummer (1991) indicated that it is easier to increase the C18:0 content of milk fat with MUFA and PUFA rich supplements than to provide stearic acid (C18:0) *per se*. Increased C18:0, content in milk of the oils supplemented groups could be related to higher milk fat observed as compared to CON. C18:0 is a major regulating factor of mammary lipid secretion in goats and positively correlated with milk fat content (Chilliard et al. 2006).

The activity of Δ^9 desaturase is essential in the process of UFA synthesis. The product: precursor ratio has been used as a possible indicator of Δ^9 desaturase activity (Lock and Gransworthy 2002). The desaturase indexes for Δ^9 desaturase like C16:1, C18:1 and Δ^6 desaturase were decreased ($p<0.05$) for SBO, RBO and SRBO as compared to CON. This may be attributed to the increase in the C18:0 concentrations in the milk, probably arising from ruminal biohydrogenation of linoleic acid (Ferreira et al. 2018). According to Simpuolus et al. (1999), recommended range of the n-6:n-3 for human health is between 5:1 and 10:1. Present finding supported that observed ratio was well within normal limit when supplemented with soybean oils (Bouattour et al. 2008; Manso et al. 2011) and rice bran oil (Maia et al. 2006).

Lipid quality indices (LQI) like atherogenic (AI), thrombogenic (TI), peroxidisability (PI), hypercholesterolaemic and hypocholesterolaemic (h/H) indices are presented in table 5. Atherogenicity index indicates relationship between the sum of main SFA and that of main classes of UFA, the former being considered as proatherogenic and later being considered as antiatherogenic (Ulbricht and Southgate 1991). Atherogenicity index was reduced ($p<0.01$) in

SBO, RBO and SRBO as compared to CON. Reduction in short and medium chain fatty acids might be responsible for decreased atherogenicity index of milk (Ibrahim et al. 2020, Bouattour et al. 2008). Thrombogenicity index (TI), indicates a tendency for clots to form in the blood vessels, was significantly lower in oils supplemented groups as compared to CON. Relatively high hypocholesterolaemic/hypercholesterolaemic (h/H) ratio is desirable, because the higher the values of h/H ratio, the lower the proportion of hypercholesterolaemic fatty acids C14:0 and C16:0 and their effect on low density lipoprotein (LDL) increases (Osmari et al. 2011). In present findings, h/H ratio was significantly ($p<0.001$) increased in SBO, RBO and SRBO as compared to CON. Lower AI and TI with higher h/H indices represent healthy animal product with consumer perspective (Janina et al. 2020). Peroxidizability index represents the relationship between FA composition and its susceptibility to oxidation and used to access the stability of PUFA included in food products. However, higher the PI value, greater the protective potential for coronary artery disease (Janina et al. 2020). In present findings, PI was significantly higher in oils supplemented groups as compared to control, which was highest in SBO followed by RBO, SRBO and CON. Elongases, responsible for elongation and extension of long chain fatty acid, was significantly ($p<0.01$) increased in all three oils supplemented groups as compared to control.

Pearson corelation between milk fat concentration and milk fatty acid composition is presented in table 6. Significant positive corelation found between milk fat and PUFA ($r=0.42$) especially with linoleic acid ($r=0.41$). This might be due to both the oils are n-6 PUFA rich which was reflected in milk fatty acid profile. Further, atherogenicity index ($r=-0.86$) and thrombogenicity index ($r=-0.93$) were also found significant negative corelation with linoliec acid. n-6: n-3 ratio was also negatively correlated with atherogenicity index(-0.51). Manso et al. (2011) found positive corelation ($r=0.67$) between linoliec acid and PUFA content of milk.

317 **Table 5: Milk fatty acid composition (% FAME) of experimental animals supplemented**

318 **vegetable oil**

FA	CON	SBO	RBO	SRBO	SEM	P VALUE
C4:0 butyric	0.06^{c}	0.05^{c}	0.16^{b}	0.26^{a}	0.02	0.001
C6:0 caproic	0.58	0.47	0.60	0.71	0.03	0.093
C8:0 caprylic	1.52	1.03	0.93	0.95	0.09	0.071
C10:0 capric	5.00^{a}	3.34^{ab}	2.60^{b}	2.47^{b}	0.32	0.009
C12:0 lauric	3.03^{a}	1.71^{b}	1.39^{b}	1.35^{b}	0.20	0.002
C14:0 myristic	7.65^{a}	4.95^{b}	4.26^{b}	4.10^{b}	0.42	0.003
C15:0 pentadecanoic	1.32^{a}	0.83^{b}	0.77^{b}	0.91^{b}	0.05	0.001
C16:0 palmitic	22.99^{a}	18.48^{b}	20.20^{b}	18.74^{b}	0.47	0.001
C16:1 palmitoleic	0.71	0.70	0.76	0.76	0.10	0.996
C17:0 heptadecanoic	1.34^{a}	0.80^{b}	0.70^{b}	0.77^{b}	0.06	0.001
C18:0 stearic	12.86^{b}	17.46^{a}	18.27^{a}	18.00^{a}	0.69	0.007
C18:1 n-9 oleic	35.09^{b}	38.91^{ab}	40.76^{a}	40.49^{ab}	0.81	0.036
C18:2 n-6 linoleic	1.44^{b}	3.02^{a}	2.83^{a}	2.86^{a}	0.16	0.001
C18:3 n-3 linolenic	0.24	0.30	0.28	0.26	0.01	0.139
C20:0 arachidic	0.58	0.54	0.67	0.69	0.02	0.058
C20:4 n-6 arachidonic	0.13	0.17	0.13	0.16	0.01	0.307
C20:5 n-3 eicosenoic	0.02	0.02	0.01	0.01	0.01	0.064
C22:0 behenic	0.23	0.20	0.19	0.23	0.01	0.539
C22:6 n-3 docosahexaenoic	0.06	0.05	0.05	0.05	0.01	0.844
C24:0 lignoceric	0.08	0.06	0.08	0.08	0.01	0.145
Others	4.52	6.07	3.54	5.45	0.47	0.252
SFA	57.24^{a}	49.90^{b}	50.83^{b}	49.25^{b}	0.99	0.007

UFA	37.69[b]	43.17[ab]	44.82[a]	44.58[a]	0.93	0.012
MUFA	35.80[b]	39.61[ab]	41.52[a]	41.25[a]	0.86	0.050
PUFA	1.89[b]	3.56[a]	3.31[a]	3.34[a]	0.16	0.001
n-6	1.57[b]	3.19[a]	2.96[a]	3.01[a]	0.13	0.001
n-3	0.32	0.37	0.34	0.32	0.01	0.427
n-6/n-3	5.06[b]	8.78[a]	8.87[a]	9.78[a]	0.58	0.009
SCFA (4-10)	7.15[a]	4.88[b]	4.29[b]	4.38[b]	0.42	0.038
MCFA (12-16)	35.71[a]	26.67[b]	27.38[b]	25.86[b]	1.04	0.001
LCFA (>16)	52.62[b]	62.39[a]	64.79[a]	64.31[a]	1.35	0.001
C16:1 desaturase index[1]	0.04[a]	0.03[b]	0.03[b]	0.03[b]	0.01	0.049
C18:1 desaturase index[2]	0.73[a]	0.69[b]	0.69[b]	0.69[b]	0.01	0.029
D5 desaturase index[3]	0.86[b]	0.90[a]	0.92[a]	0.92[a]	0.01	0.010
D6 desaturase index[4]	0.09[a]	0.05[b]	0.04[b]	0.05[b]	0.01	0.001
Atherogenicity index[5]	1.56[a]	0.94[b]	0.87[b]	0.82[b]	0.09	0.001
Thrombogenecity index[6]	2.04[a]	1.70[b]	1.70[b]	1.64[b]	0.06	0.050
h/H index[7]	1.23[b]	1.85[a]	1.82[a]	1.92[a]	0.08	0.001
Elongase[8]	0.65[b]	0.75[a]	0.74[a]	0.75[a]	0.01	0.001
Peroxidisability index[9]	4.49[b]	6.66[a]	6.24[a]	5.90[a]	0.21	0.001

abc -Means with different superscript in a row differ significantly ($p<0.05$)

[1]16:1 desaturase index=C16:1/(C16:1+C16:0)

[2]18:1 desaturase index=C18:1/(C18:1+C18:0) (Kelsey et al. 2003)

[3]Delta 5 desaturase index =C20:4 n-6/C20:3 n-6+ C20:4 n-6

[4]Delta 6 desaturase index=C20:3 n-6/C18:2 n-6+ C20:3 n-6 (Nudda et al. 2008)

[5]Atherogenicity index=(12:0+4*14:0+16:0)/(MUFA+PUFA) (Ulbricht and Southgate 1991).

[6]Thrombogenicity index (TI)=[(C14:0+C16:0+C18:0)/(0.5*MUFA+0.5*PUFAn6 + 3*PUFAn3+ (PUFAn3/PUFAn6))].

[7]h/H(hypocholesterolaemic/hypercholesterolaemic)=(C18:1n9+C18:2n6+C20:4n6+C18:3n3+ C20:5n3+C22:6n3)/(C14:0+C16:0) (Santos-Silva et al. 2002)

[8]Elongase= C18:0+C18:1 c9/ (C16:0 +C16:1+ (C18:0+C18:1c9))(Oliviera et al.2014)

[9]Peroxidisability index (PI)=(0.025*monoenes) + (1*dienes) + (2*trienes) + (4*tetraenes) + (6*pentaenes) + (8*hexaenes) (Erickson et al. 1992)

Table 6: Pearson correlation between milk fat concentration and milk fatty acid composition

	OA	LA	LnA	SFA	MUFA	PUFA	n6:n3	SCFA	MCFA	LCFA	AI	TI
Fat	-0.04	0.41 *	0.29	-0.11	-0.07	0.42 *	0.27	-0.01	-0.27	0.44 *	-0.13	-0.01
OA		0.42 *	0.20	-0.84 **	0.99 **	0.41 *	0.31	-0.80 **	-0.66 **	0.83 **	-0.86 **	-0.93 **
LA			0.22	-0.61 **	0.37	0.99 **	0.84 **	-0.52 **	-0.80 **	0.70 **	-0.65 **	-0.42 *
LnA				-0.24	0.19	0.28	-0.28	-0.24	-0.31	0.30	-0.30	-0.23
SFA					-0.84 **	-0.61 **	-0.48 *	0.84 **	0.84 **	-0.80 **	0.94 **	0.92 **
MUFA						0.37	0.27	-0.78 **	-0.62 **	0.78 **	-0.85 **	-0.94 **
PUFA							0.82 **	-0.52 **	-.081 **	0.70**	-0.66 **	-0.42 *
n6:n3								-0.42 *	-0.64 **	0.55 **	-0.51 *	-0.29
SCFA									0.84 **	-0.90 **	0.93 **	0.74 **
MCFA										-0.91 **	0.93 **	0.67 **
LCFA											-0.94 **	-0.73 **
AI												0.87 **
TI												

OA- Oleic acid; LA- Linoleic acid; LnA- Linolenic acid; SFA- Saturated fatty acid; MUFA-Mono unsaturated fatty acid; PUFA- Polyunsaturated fatty acid; SCFA- Short chain fatty acid; MCFA- Long chain fatty acid; LCFA- Long chain fatty acid; AI- Atherogenicity index, TI-Thrombogenicity index, * $p<0.05$; ** $p<0.01$; *** $p<0.001$

Ruminal parameters

Ruminal parameters like pH, ammonia nitrogen, total nitrogen and its fraction were at par amongst treatments and within normal range. Ruminal pH was not affected by diet or sampling time and was ideal for normal digestibility of fiber in rumen (Orskov 1994). Reduced fiber digestibility and microbial synthesis have been observed when rumen pH falls below 6.2 (De veth & Kolver 2001). Non significant ($p>0.05$) ADF and NDF digestibility also suggest that oils supplementation did not affect fiber digestion.

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. TVFA concentration in the rumen depends on many factors including nutrient digestibility, rumen pH, rate of digesta passage from rumen, rate of absorption as well as the microbial population in the rumen and their activities (Morsy et al. 2015). The higher concentration of TVFA in SBO, RBO and SRBO indicates more efficient anaerobic fermentation.

Ruminal ammonia-N did not differ ($p>0.05$) significantly with both diet and time. In the present study, the concentrations of rumen ammonia-N (Table 7) was above the minimum concentrations required (≥ 5 mg/dL) for rumen microbial growth and for optimum fiber degradation in the rumen (Morsy et al. 2015).

Ammonia-N level depends on mainly upon dietary CP solubility. 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 in ruminants. However, an

extensive review by Doreau and Ferlay (1995) suggested little or no effect of dietary lipid on ammonia-N concentration. Total nitrogen (mg/dl), TCA precipitable nitrogen (mg/dl) and soluble nitrogen (mg/dl) did not differ either with diet or sampling time.

Table 7: Effect of vegetable oil supplementation on ruminal fermentation of experimental animal

Parameters	CON	SBO	RBO	SRBO	SEM	P value		
						D	T	D x T
pH	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; DxT- Diet and time interaction; SEM- Standard error of mean

abc -Means with different superscript in a row differ significantly ($p<0.05$)

Conclusions

Addition of soybean oil and/or rice bran oil showed significant improvement in nutritional quality of milk fat with respect to FA composition and lipid quality indices (LQI) of milk. Both the vegetable oils either alone or in combination, increased production performance of Surti does in terms of milk yield, fat content and FCM of milk. However, results were more promising in

individual oil supplemented groups as compared to mixture of oil. Supplementation of both the oils alone or in combination had no adverse effect on nutrient utilization and ruminal fermentation of Surti does.

Declarations:

Funding: The authors are thankful to authorities and Vice chancellor of Navsari Agricultural University for providing funding, support and facilities.

Competing interest: The authors declare that they have no competing interest.

Ethical approval: All applicable international, national and/or institutional guidelines for the care and use of animals were followed. The experiment (no. 052-VCN-ANN-2017) was approved by Institutional Animal Ethic Committee (IAEC/CPCSEA Reg No. 1631/GO/Re-SL/Bi-S/12/CPCSEA)

Consent to participate: Not applicable

Availability of data and material: Not applicable

Code availability: Not applicable

Author's contribution: APR - Designed research work, statistical analysis of project and manuscript writing. VRP - Sample collection and analysis. LMS and JKM - Execution of research work. All authors read and approved the manuscript.

References

Adeyemi, K.D., Sazili, A.Q., Ebrahimi, M., Samsuddin, A.A., Alimon, A.R., Karim, R., Karsani, S.A. and Sabow, A.B. 2015. Effects of blend of canola oil and palm oil on nutrient intake and digestibility, growth performance, rumen fermentation and fatty acids in goats, Animal Science Journal, 86,270-278.

393 Adeyemi, K.D., Sabow, A.B., Aghwan, Z.A., Ebrahimi, M., Samsuddin, A.A, Alimon, A.R. and
394 Sazili, A.Q. 2016. Serum fatty acids, blood biochemical indices and antioxidant status in
395 goats fed with canola oil and palm oil blend, Journal of Animal Feed Science and
396 Technology, 58,1-6.
397 Almeida, O.C., Ferraz, M.V., Susin, I, Gentil, R.S., Polizel, D.M., Evandro, M., Ferreira, E.M.,
398 Barroso, J.P. and Pires, A.V. 2019. Plasma and milk fatty acid profiles in goats fed diets
399 supplemented with oils from soybean, linseed or fish, Small Ruminant Research, 170,125-
400 130.
401 AOAC. 2005. Official Methods of Analysis. Association of Official Analytical Chemist, 18th ed.
402 Washington, DC.
403 Attaie, R. and Richter, R.L. 2000. Size distribution of fat globules in goat milk, Journal of Dairy
404 Science, 83,940-944.
405 Barnett, J.G. and Reid, R.L. 1956. Studies on the production of volatile fatty acids from the grass
406 by rumen liquor in an artificial rumen, The Journal of Agricultural Sciences, 48,315-321.
407 Bernard, L., Shingfield, K.J., Rouel, J., Ferlay, A. and Chilliard, Y. 2009. Effect of plant oils in
408 the diet on performance and milk fatty acid composition in goats fed diets based on grass
409 hay or maize silage, The British Journal of Nutrition, 101,213-224.
410 Bernard, L., Leroux, C., Rouel, J., Delavaud, C., Shingfield, K.J. and Chilliard, Y. 2015. Effect
411 of extruded linseeds alone or in combination with fish oil on intake, milk production,
412 plasma metabolite concentrations and milk fatty acid composition in lactating goats,
413 Animal, 9(5),810-821.

414 Bouattour, M.A., Casals, R., Albanell, E., Such, X. and Caja, G. 2008. Feeding soybean oil to
415 dairy goats increases conjugated linoleic acid in milk, Journal of Dairy Science, 91,2399-
416 2407.
417 Chilliard, Y., Ferlay, A., Rouel, J. and Lamberet, G. 2003. A review of nutritional and
418 physiological factors affecting goat milk lipid synthesis and lipolysis, Journal of Dairy
419 Science, 86,1751-1770.
420 Chilliard, Y., Rouel, J., Ferlay, A., Bernard L., Gaborit, P., Rynal-Ljitovac, K., Lauret, A. and
421 Leroux, C. 2006. Optimising goat's milk and cheese fatty acid composition. In, Improving
422 the fat content of foods, [Williams, C. and Buttriss, J. (eds.)]. Cambridge, UK, Woodhead
423 Publishing Limited. pp,281-312.
424 De Veth, M. and Kolver, E. 2001. Diurnal variation in pH reduces digestion and synthesis of
425 microbial protein when pasture is fermented in continuous culture, Journal of Dairy
426 Science, 84,2066-72.
427 Doreau, M. and Ferlay, A. 1995. Effect of dietary lipids on nitrogen metabolism in the rumen, A
428 review, Livestock Production Science, 43,97-110.
429 Erickson, M.C. 1992. Variation of lipid and tocopherol composition in three strains of channel
430 catfish (*Ictalurus punctatus*), Journal of the Science of Food and Agriculture, 59,529-536.
431 Ferreira, E.M., Ferraz, M.V., Polizel, D.M., Urano, F.S., Susin, I., Gentil, R.S., Biehl, M.V.,
432 Biava, J.S. and Pires, A.V. 2018. Milk yield and composition from ewes fed raw soybeans
433 and their lamb's performance, Animal Feed Science and Technology, 238,1-8.
434 Gomes, J.J.L., Duarte, A.M., Batista, A.S.M., Figueiredo, R.M.F., Sousa, E.P., Souza, E.L. and
435 Queiroga, R.C. 2013. Physicochemical and sensory properties of fermented dairy

436 beverages made with goat's milk, cow's milk and a mixture of the two milks, Food Science
437 and Technology, 54,18-24.
438 Gómez-Cortés, P., Frutos, P., Mantecón, A.R., Juárez, M., De La Fuente, M.A. and Hervás, G.
439 2008. Milk production, conjugated linoleic acid content and in vitro ruminal fermentation
440 in response to high levels of soybean oil in dairy ewe diet, Journal of Dairy Science,
441 91,1560-1569.
442 Grummer, R.R. 1991. Effect of feed on the composition of milk fat, Journal of Dairy Science,
443 74(9),3244-3257.
444 Haenlein, G.F.W. 2004. Goat milk in human nutrition, Small Ruminant Research, 51,155-63.
445 Hassan, L.K., Shazly, A.B., Kholif, A.E., Sayed, A.F. and Aziz, M.A. 2020. Effects of flaxseed
446 (*Linum ustitatissimum*) and soybean oil (*Glycine max*) oils in Egyptian lactating buffalo
447 and cow diets on the milk and soft cheese quality, Acta Scientanarium, pp,1-12. Doi,
448 10.4025/actascianimsci.v42i1.47200.
449 Ibrahim, A.H. and Soryal, K.A. 2014. Effect of using cross linked β-cyclodextrin on
450 physicochemical properties of Domiati goat's cheese, Journal of Food and Dairy Science,
451 5(8),581-600.
452 Ibrahim, A.H., Younis, F.E., Abdeen, E.M. and El-Shafei, S.M. 2020. Effect of flaxseed
453 supplementation on milk production, chemical composition, physical attributes and fatty
454 acid profile of milk in lactating goats of halayeb-shalateen-aburamad triangle of Egypt,
455 Animal Science Reporter, 13(1),1-22.
456 ICAR. 2013. Nutrient requirements of sheep, goat and rabbit. Indian Council of Agricultural
457 Research, New Delhi. India.

458 ISO-IDF. 2002. Milk fat-preparation of fatty acid methyl esters. International Standard ISO
459 15884-IDF 182,2002.
460 Janina, W., Gabriela, H., Okuruszek, A., Monika, W., Zuzanna, G. and Miroslva, T. 2020. Fatty
461 acid profile and health indices in the breast muscle of local Polish goose varieties, Poultry
462 Science, 99,1216-1224.
463 Kelsey, J.A., Corl, B.A., Collier, R.J. and Bauman, D.E. 2003. The effect of breed, parity and
464 stage of lactation on conjugated linoleic acid (CLA) in milk fat from dairy cows, Journal of
465 Dairy science, 86(8),2588-2597.
466 Kholif, A.E., Morsy, T.A. and Abdo, M.M. 2018. Crushed flaxseed versus flaxseed oil in the
467 diets of Nubian goats, effects on feed intake, digestion, ruminal fermentation, blood
468 chemistry, milk production, milk composition and milk fatty acid profile, Animal Feed
469 Science and Technology, 244,66-75.
470 Li, X.Z., Yan, C.G., Long, R.J., Jin, G.L., Shine Khuu, J., Ji, B.J., Choi, S.H., Lee H.G. and
471 Song, M.K. 2009. Conjugated linoleic acid in rumen fluid and milk fat and methane
472 emission of lactating goats fed a soybean oil-based diet supplemented with sodium
473 bicarbonate and monensin, Asian-Australasian Journal of Animal Sciences, 11,1521-1530.
474 Li, X.Z., Choi, C.W., Yan, C.G., Shin, J.S. and Smith, S.B. 2016. Dietary linseed oil with or
475 without malate increases conjugated linoleic acid and oleic acid in milk fat and lipoprotein
476 lipase and stearoyl-coenzyme A desaturase gene expression in mammary gland and milk
477 somatic cells of lactating goats, Journal of Animal Science, 94, 3572-3583.
478 Lock, A.L. and Garnsworthy, P.C. 2002. Independent effects of dietary linoleic and linolenic
479 fatty acids on the conjugated linoleic acid content of cow's milk, Animal Science, 74,163-
480 176.

481 Lunsin, R., Wanapat, M., Yuangklang, C. and Rowlinson, P. 2012. Effect of rice bran oil
482 supplementation on rumen fermentation, milk yield and milk composition in lactating dairy
483 cows, Livestock Science, 145,167-173.
484 Maia, J.B., Branco, A.F., Mouro, G.F., Coneglian, S.M., Santos, G.T., Minella, T.F. and
485 Guimaraes, K.C. 2006. Feeding vegetable oil to lactating goats, milk production and
486 composition and milk fatty acids profile, Brazilian Journal of Animal Science, 35(4),1-13.
487 https,//doi.org/10.1590/S1516-35982006000500033
488 Manso, T., Bodas, R., Vieira, C., Mantecon, A.R. and Castro, T. 2011. Feeding vegetable oils to
489 lactating ewes modifies the fatty acid profile of suckling lambs, Animal, 5(10),1659-1667.
490 Mele, M., Serra, A., Buccioni, A., Conte, G., Pollicardo, A. and Secchiari, P. 2008. Effect of
491 soybean oil supplementation on milk fatty acid composition from Sannen goats fed diets
492 with different forage, concentrate ratios, Italian Journal of Animal Science, 7,297-311.
493 Messana, J.D., Berchielli, T.T., Arcuri, P.B., Reis, R. A., Canesin, R. C. and Ribeiro, A.F. 2013.
494 Rumen fermentation and rumen microbes in Nellore steers receiving diets with different
495 lipid contents, Revista Brasileira De Zootecnia, 42,204-12.
496 Morsy, T.A, Kholif, S.M., Kholif, A.E., Matloup, O.H., Salem, A.Z. and Abu Elella, A. 2015.
497 Influence of sunflower whole seeds or oil on ruminal fermentation, milk production,
498 composition and fatty acid profile in lactating goats, Asian-Australasian Journal of Animal
499 Sciences, 28,1116-1122.
500 Morsy, T.A., Kholif, A.E., Matloup, O.H., Elella, A.A., Anele U.Y. and Caton, J.S. 2018.
501 Mustard and cumin seeds improve feed utilisation, milk production and milk fatty acids of
502 Damascus goats, Journal of Dairy Research, pp, 1- 10. doi,10.1017/S0022029918000043.

503 Nudda, A., Battacone, G., Usai, M.G., Fancellu, G. and Pulina, G. 2006. Supplementation with
504 extruded linseed cake affects concentrations of conjugated linoleic acid and vaccenic acid
505 in goat milk, Journal of Dairy Science, 89(1),277- 282.
506 Nudda, A., Palmquist, D.L., Battacone, G., Fancellu, S.S., Rassu, P.G. and Pulina, G. 2008.
507 Relationships between the contents of vaccenic acid, CLA and n-3 fatty acids of goat milk
508 and the muscle of their suckling kids, Livestock Science, 118,195-203.
509 Nudda, A., Battacone, G., Neto, O.B., Cannas, A., Francesconi, A.H., Atzori, A.A. and Pulina,
510 G. 2014. Feeding strategies to design the fatty acid profile of sheep milk and cheese,
511 Revista Brasileira de Zootecnia, 43(8),445-56.
512 Nudda, A., Battacone, G., Bee, G., Boe, R., Castanares, N., Lovicu, M. and Pulina, G. 2015.
513 Effect of linseed supplementation of the gestation and lactation diets of dairy ewes on the
514 growth performance and the intramuscular fatty acid composition of their lambs, Animal,
515 9(5),800-809.
516 O'Fallon, J.V., Busboom, J.R., Neison, M.L. and Gaskins, C.T. 2007. A direct method for fatty
517 acid methyl esters synthesis, Application to wet meat tissues, oils and feedstuffs, Journal of
518 Animal Science, 85,1511-1521.
519 Oliveira, E.A., Chalfun-Junior, A., Chizzotti, M.L., Barreto, H.G., Coehlo, T.C., Paiva, L.V.,
520 Coelho, C.P., Teixeira, P.D., Shoonmaker, J.P. and Ladeira, M.M. 2014. Expression of
521 genes involved in lipid metabolism in the muscle of beef cattle fed soybean or rumen-
522 protected fat with or without monensin supplementation, Journal of Animal Science,
523 92(12), 5426-5436.
524 Orskov, E. 1994. Recent advances in understanding of microbial transformation in ruminants,
525 Livestock Production Science 39,53-60.

526 Osmari, E.K., Cecato, U., Macedo, F.A. and Souza, N.E. 2011. Nutritional quality indices of
527 milk fat from goats on diets supplemented with different roughages, Small Ruminant
528 Research, 98,128-132.
529 Palmquist, D.L., Lock, A., Shingfield, K.J. and Bauman, D.E. 2005. Biosynthesis of conjugated
530 linoleic acid in ruminants and humans. In Advances in Food and Nutrition Research. Vol.
531 50. S. L. Taylor, ed. Elsevier Academic Press, San Diego, CA, USA. pp, 179-217.
532 Pascual, A., Pineda-Quiroga, C., Goiri, I., Atxaerandio, R., Ruiz, R. and García-Rodríguez, A.
533 2019. Effects of feeding UFA-rich cold-pressed oilseed cakes and sainfoin on dairy ewe's
534 milk fatty acid profile and curd sensory properties, Small Ruminant Research, 175,96-103
535 Reyes, I.L., Martínez, G.D., Rubio, R.R., Mejia, M., Lopez, J.C. and Rangel, H.A. 2018.
536 Influence of supplemental canola or soybean oil on milk yield, fatty acid profile and
537 postpartum weight changes in grazing dairy goats, Asian-Australasian Journal of Animal
538 Sciences, 31(2),225-229.
539 Santos-Silva, J., Bessa, R.J.B. and Santos-Silva, F. 2002. Effect of genotype, feeding system and
540 slaughter weight on the quality of light lambs, Livestock Production Science, 77(3),187-
541 194.
542 Simopoulos, A.P., Leaf, A. and Salem, N. 1999. Essentiality and recommended dietary intakes
543 for omega-6 and omega-3 fatty acids. Annals of Nutrition and Metabolism, 43,127-130.
544 Sjaunja, L.O., Baevre, L., Junkkarinen, L., Pedersen, J. and Setala, J. 1991. A nordic proposal for
545 an energy corrected milk (ECM) formula. Performance recording of animals, State of the
546 art. EAAP Publication, 50,156-157.

547 Titi H.H. and Rahman, A.A. 2013. Effect of supplementation with vegetable oil on performance
548 of lactating Awassi ewes, growth of their lambs and on fatty acid profile of milk and blood
549 of lambs, Archives Animal Breeding, 56,467-479.
550 Tyrrell, H.F. and Reid, J.T. 1965. Prediction of the energy values of cow's milk. Journal of Dairy
551 Science, 48,1215-1223.
552 Ulbricht, T.L.V. and Southgate, D.A.T. 1991. Coronary heart disease, seven dietary factors,
553 Lancet, 338,985-992.
554 Van Soest, P.J., Robertson, J.B. and Lewis, B.A. 1991. Methods of dietary fibre, neutral
555 detergent fibre and non-starch polysaccharide in relation to animal nutrition, Journal of
556 Dairy Science,74,3583-3597.