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Morteza Hosseini Ghaffari [a], Abdol Mansour Tahmasbi [a], Mohammad Khorvash [b], Abbas Ali Naserian [a] & Ali Reza Vakili [a]

[a] Faculty of Agriculture, Department of Animal Science, Ferdowsi University of Mashhad, Mashhad, Iran

[b] Faculty of Agriculture, Department of Animal Science, Isfahan University of Technology, Isfahan, Iran

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Effects of pistachio by-products in replacement of alfalfa hay on ruminal fermentation, blood metabolites, and milk fatty acid composition in Saanen dairy goats fed a diet containing fish oil

Morteza Hosseini Ghaffari[a]*, Abdol Mansour Tahmasbi[a], Mohammad Khorvash[b], Abbas Ali Naserian[a] and Ali Reza Vakili[a]

[a]*Faculty of Agriculture, Department of Animal Science, Ferdowsi University of Mashhad, Mashhad, Iran;* [b]*Faculty of Agriculture, Department of Animal Science, Isfahan University of Technology, Isfahan, Iran*

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The objective of this study was to investigate the effects of pistachio by-products (PBP) in replacement of alfalfa hay (AH) on ruminal fermentation, blood metabolites, and milk fatty acid composition in Saanen dairy goats fed a diet containing fish oil. For this purpose, 15 multiparous lactating Saanen goats (on day 25 postpartum, 38.15 ± 1.2 kg) were randomly assigned to three treatment diets in a completely randomized design with five goats per treatment. The treatment consisted of feeding the following diets: (1) control (AH), (2) 30% PBP, and (3) 30% PBP + polyethylene glycol (PEG, 1 g/Kg of dry matter [DM]). The experiment lasted 21 days, including 16 days of adaptation to the experimental diets followed by a five-day sampling period for determining milk yield and composition, dry matter intake (DMI), and blood metabolites. The results showed that DMI was affected ($P < 0.05$) by using PBP in the diets. The goats fed PBP had a lower ($P < 0.05$) DMI than those in other treatments. No differences were observed in milk yield and composition among the dietary treatments. The goats fed PBP (with and without PEG) had higher ($P < 0.05$) amounts of C16:0 and trans-C18:1 isomer in their milk fat than those fed AH. C24:0 was detected at higher ($P < 0.05$) concentrations in goats fed AH than those in other treatments. Overall, different treatments had no significant effects on the concentrations of saturated, monounsaturated, and polyunsaturated fatty acids (PUFA) in milk fat. Trans fatty acids (TFA) in milk fat exhibited higher ($P < 0.05$) concentrations in PBP and PBP-PEG treatments than in AH. However, no differences were detected in the concentrations of short, medium, and long chain fatty acids among the treatments. No differences were observed in rumen pH among the treatments, while rumen ammonia-N concentrations were lower ($P < 0.01$) in goats fed PBP than those in the other treatments. Treatments showed no differences with regard to blood metabolites (i.e., cholesterol, triglyceride, blood urea nitrogen, total protein, albumin, and glucose). These findings indicate that the inclusion of PBP in replacement of AH in the diet of dairy Saanen goats have no adverse effects on ruminal fermentation and blood metabolites. Moreover, PBP is capable of modifying the fatty acid profile of milk in dairy goat.

Keywords: pistachio by-products; fish oil; milk fatty acid; polyethylene glycol; Saanen goats

1. Introduction

The use of locally available feed resources has great potential for improving goat production in developing countries (Argüello 2011). Iran is considered to be the largest producer of pistachio worldwide, with an annual production of approximately 500,000 tons of fresh pistachio by-products (PBP; Shakeri et al. 2012). While PBP is high in protein (158.2 g/kg) and ether extract (EE; 69.5 g/kg) and, hence, a valuable feed for ruminants (Behgar et al. 2009), its nutritive value is subject to variation due to the dehulling process, pistachio cultivar, and growing conditions (Bagheripour et al. 2008). The total phenolic compounds and total tannins of sun-dried PBP have been reported to be 7.6–15.6% DM and 3.4–10.15% DM, respectively (Shakeri & Fazaeli 2007; Bagheripour et al. 2008; Bohluli et al. 2009).

Tannins have also been reported to bind preferentially with polyethylene glycol (PEG) whose supplementation has been used to eliminate and evaluate the effects of tannins (Decandia et al. 2000). Pistachio by-products have recently come to be used as feedstuff in ruminant nutrition in Iran (Vahmani and Naserian 2005; Gholizadeh et al. 2010). Norouzian and Ghiasi (2012) reported that the performance of fattening lambs was not affected by feeding dried PBP by up to 30% of the diet DM. Shakeri et al. (2012) included PBP silage by up to 18% of the diet for Holstein male calves and reported no adverse effects on the dry matter intake (DMI), growth performance, and blood parameters after a long-term feeding program. Several studies have shown that diets containing moderate levels of tannins lead to reduced degradation of proteins in the rumen followed by more essential

*Corresponding author. Email: morteza.h.g@gmail.com

amino acids absorbed in the small intestine (Min et al. 2003; Frutos et al. 2004). Milk fatty acid composition has been shown to be affected by dietary oil supplementation (Huang et al. 2008). A number of studies have also demonstrated that dietary fish oil supplements alter the pathways of ruminal biohydrogenation, and lead to the accumulation of trans-11 C18:1 in milk (Abu-Ghazaleh et al. 2002; Whitlock et al. 2002). Donovan et al. (2000) reported that dietary inclusion of fish oil (20 g/kg of diet DM) increased cis-9, trans-11 conjugated linoleic acid concentrations in milk. It is thought that tannins interfere with ruminal biohydrogenation, more specifically inhibiting the last step of biohydrogenation, which converts trans-vaccenic acid to stearic acid and thereby favorably alters milk fatty acid composition (Khiaosa-Ard et al. 2009; Vasta et al. 2010; Toral et al. 2011). To the best of the authors' knowledge, no published reports are available on the possible effects of PBP (containing high levels of phenolic compounds and tannins) on milk fatty acid composition in goats fed diets containing fish oil. The objective of the present investigation is to determine the effect of PBP on feed intake, ruminal fermentation, and blood metabolites. As its second objective, the study aims to determine whether dietary PBP affects the milk fatty acid composition in Saanen dairy goats.

2. Material and methods

2.1. Animals, experimental diets, and management

The experiment was conducted at the Research Farm of the Faculty of Agriculture, Ferdowsi University of Mashhad (Iran), in 2012. The experimental protocols were reviewed and approved by the Animal Care Committee of the university. Fifteen multiparous lactating Saanen goats (on day 25 postpartum, 38.15 ± 1.2 kg) were randomly assigned to the three treatment diets in a completely randomized design with five goats per treatment, each kept in an individual pen. The basal diet consisted of 300 g/kg alfalfa hay (AH), 200 g/kg corn silage, and 250 g/kg barley on a DM basis. Treatments consisted of the following diets: (1) control (AH), (2) 30% PBP, and (3) 30% PBP + PEG-4000, 1 g/Kg of DM. The experiment lasted 21 days including 16 days of treatment adaptation and 5 days of data collection. The animals received total mixed ration daily at 08:00 h. Sun-dried PBP, which contained soft external hull, twinges, leaves, and bony shells, were collected from Bardaskan Town (Babakhan Co., Khorasan-e-Razavi Province, Iran). *Kilka* (*Clupeonella engrauliformis*) fish oil obtained from Negin-Poodr (Negin-Poodr Co., Amir-Abad Port, Iran) was stored at 4°C before it was mixed evenly with the concentrate each morning and added to all the treatment diets. The ingredients and chemical composition of the diets, and the fatty acid composition of PBP and fish oil are presented in Tables 1 and 2, respectively.

2.2. Measurements and sampling procedures

2.2.1. Diets and milk sampling

The amount of feed and refusals were collected from each animal daily. For each diet, a sample of the feed was collected and subsequently used for chemical analysis. The goats were milked daily at 09:00 and individual yields were recorded at each milking on days 16, 17, 18, 19, 20, and 21. Milk samples were obtained from each goat for five consecutive milkings during the trial and pooled on a yield basis after freezing and thawing. One sample was stored at 4 °C with a preservative (bronopol-B2) and sent to a laboratory (Food and Chemical Analysis Research Laboratory, Jahad-e-Daneshgahi, Mashhad, Iran) to be analyzed for its fat, protein, and lactose contents, using a MilkoScan 4000 infrared analyzer (Foss Electric, Hillerød, Denmark). Another sample with-

Table 1. Ingredient composition of experimental diets.

Item	Treatment		
	AH	PBP	PBP + PEG[a]
Ingredients, %			
Alfalfa hay	30	0	0
Pistachio by-products	0	30	30
Barley	25	25	25
Corn silage	20	20	20
Canola meal	14	17	17
Wheat bran	7	4	4
Fish oil	2	2	2
Vitamin-mineral mix[b]	1	1	1
Calcium carbonate	0.5	0.5	0.5
Salt	0.5	0.5	0.5
Chemical composition, % of DM			
CP	14.7	14.7	14.7
Ether extract	4.7	6.1	6.1
NDF	36.7	33.7	33.7
ADF	23.1	20.5	20.5
NFC[c]	39.5	40.1	40.1
Calcium[d]	1	0.9	0.9
Phosphorus[d]	0.6	0.5	0.5
Total phenols	0.81	3.31	3.31
Total tannins	0.44	1.81	1.81

AH = alfalfa hay, PBP = pistachio by-product, PBP + PEG = pistachio by-product + PEG.
[a]The PEG group received the tannin diet with 40 g of PEG-6000 added for each kilogram of diet.
[b]Contained (/kg of premix; DM basis): 330,000 IU of vitamin A, 60,000 IU of vitamin D, 1000 IU of vitamin E, 160 g Ca, 85 g P, 63 g Na, 45 g Mg, 2100 mg Zn, 1500 mg Mn, 535 mg Cu, 12 mg Se, 45 mg I.
[c]NFC calculated as 100 − (CP + Ash + NDF + EE).
[d]Estimated using NRC (2001).

Table 2. FA composition of PBP and fish oil.

Item	Pistachio by-product	Fish oil
Fatty acid (g/100 g of FA)		
C12:0	0.03	–
C14:0	1.47	3.03
C16:0	12.34	19.31
C16:1 cis-9	0.94	8.82
C17:0	0.18	–
C17:1 cis-9	0.09	–
C18:0	2.22	4.42
C18:1 cis-9	47.80	26.02
C18:2 cis-9, cis-12 (n-6)	26.94	3.47
C18:3 cis-9, cis-12, cis-15 (n-3)	4.72	2.54
C20:0	0.15	0.35
C20:1 cis-9	0.64	2.26
C20:5 cis-7, cis-10, cis-13, cis-16, cis-19 (n-3)	–	7.62
C22:0	0.61	–
C22:6 cis-4, cis-7, cis-10, cis-13, cis-16, cis-19 (n-3)	–	18.29
C24:0	0.61	–
Total unsaturated FA[a]	81.13	69.02
Total saturated FA[b]	17.61	27.11
Others	1.26	3.87

[a]Sum of C16:1, C17:1, C18:1, C18:2, C18:3, C20:1, C22:5, and C22:6.
[b]Sum of C12:0, C14:0, C16:0, C17:0, C18:0, C20:0, C22:0, and C24:0.

out any preservative was stored at −18 °C for analysis of fatty acids (FAs) using Gas Chromatography.

2.2.2. Rumen and blood sampling

On day 20 of the experiment, rumen fluid was collected from each goat at 3 h after the morning feeding, using a stomach tube and checked to confirm that it did not contain saliva. The rumen fluid samples were filtered through four layers of cheesecloth and immediately used to measure its pH, using a glass electrode pH-meter (691 Metrohm, Herisau, Switzerland). The ruminal fluid was subsequently acidified with 10 ml of 0.2 N HCl solution (50%, vol/vol) and stored frozen before ammonia-N analysis. Blood samples from all the goats were obtained from the jugular vein 3 h after the morning feeding (10 ml into sterile tubes containing EDTA solution) on day 21 of the experiment. The blood samples were then centrifuged at 3000 rpm for 15 minutes to obtain plasma which was separated, frozen, and stored at −18 °C until further analysis.

2.3. Chemical analysis

The DM content of feed ingredients was determined by oven-drying them at 60 °C for 48 h and analyzed for concentrations of DM, CP, and ether extract by standard procedures (AOAC 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest et al. (1991). The total phenolic content was determined according to the Folin–Ciocalteu assay, and total tannins were determined by methods previously described (Makkar 2000). Tannic acid (Merck GmbH, Darmstadt, Germany) was used as the standard to express the amount of total phenols and total tannins. No information on fatty acid composition of the diets was provided in the current study. Rumen ammonia concentrations were determined using the distillation method (Kjeltec Auto 1030 Analyzer, tecator, Hoganas, Sweden). The concentrations of cholesterol, triglyceride, blood urea nitrogen (BUN), total protein, albumin, and glucose were determined by an automated biochemical analyzer (Biotecnica, Targa 3000, Rome, Italy) using commercial kits (Pars Azmoon Co., Tehran, Iran) according to the manufacturer's instructions. Milk fat was extracted from the samples using 2:1 chloroform: methanol solution, according to the methods described by Folch et al. (1957). For this purpose, milk samples were mixed with the chloroform-methanol (2:1, v/v) solution (40 ml) by vigorous shaking for five minutes and left for incubation (12 h) with occasional shaking before adding 10 ml of normal saline. The lower chloroform phase containing lipids was subsequently collected and taken to dryness by rotary evaporation at 25 °C under vacuum (Heidolph® Laborota 4000, Germany). The extracted fat was then mixed again with 5 ml of the chloroform-methanol solution, and 100 µl of internal standard, heneicosanoic acid C21:0 (Nu-chek-prep, Inc., Elysian, MN, USA) was then added before the fatty acid methyl ester (FAME) preparation according to the method of Wijngaarden (1967). FA concentration was measured by gas chromatography (0.25 × 0.32, ID of 0.3 m WCOT Fused Silica Capillary, DANI, Model 1000, Rome, Italy) with a 120 m (0.32 mm ID) silica-fused column (BPX-70) as described by Alizadeh et al. (2012). Hydrogen was used as the carrier gas, and the initial and final temperatures were set at 50 and 190 °C respectively, with detector and injector temperatures set at 300 and 280 °C, respectively. FAs used as standards were purchased from Sigma-Aldrich (Catalog #18919).

2.4. Statistical analysis

The data was analyzed as a completely randomized design using the PROC MIXED procedure of SAS 9.1.3 (2004, SAS Institute Inc., Cary, NC, USA) with

the animal as the experimental unit according to the following model:

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

where Y_{ij} = dependent variable; μ = overall mean of the population; T_i = treatment, and ε_{ij} = unexplained residual element assumed to be independent and normally distributed. All the data were presented as least squares means obtained through the least squares means (LSMEANS) statement. Mean separations were determined using the *p*-values differences of least square means (PDIFF) statement. Least significant difference at $P < 0.05$ was used to determine significant differences among means.

3. Results

The mean of DMI, milk yield, and composition are presented in Table 3. DMI was affected ($P < 0.05$) by treatments. The goats fed PBP had the lowest ($P < 0.05$) DMI, but the difference between AH (control) and PBP + PEG treatments was not significant (Table 3). Milk yield and 4% fat-corrected milk (FCM) were not affected by dietary treatments (Table 3). The mean values for milk yield were 1.221, 1.218, and 1.198 kg per day for AH, PBP, and PBP + PEG treatments respectively (Table 3). There were no treatment effects on milk fat, protein, lactose, solid nonfat, and total solid percentage and yield (Table 3). The mean of milk fatty acid profiles are presented in Table 4. From among all the milk fatty acids, palmitic acid (C16:0) and C18:1 cis-9 were the most representative FAs in the milk fat of Saanen goats. In this study, dietary treatments had no significant effects on C4:0, C6:0, C8:0, C10:0, C11:0, C12:0, C13:0, C14:0, C14:1 cis-9, C15:0, C15:1 cis-9, C17:0, C17:1 cis-9, C18:0, C18:1 cis-9, C18:2 cis-9 cis-12, C18:3 cis-9, cis-12, cis-15, C20:0, C22:0, and C22:1 content of milk fat (Table 4). The goats fed PBP (with and without PEG) had higher ($P < 0.05$) amounts of C16:0 and trans-C18:1 isomers in their milk fat concentrations than those fed AH, while C24:0 was detected at higher ($P < 0.05$) concentration in the goats fed AH than those in other treatments. Overall, the different treatments had no effects on the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) concentrations in milk fat (Table 5). Higher concentrations of trans fatty acids (TFA) in milk fat ($P < 0.05$) were observed with the PBP and PBP-PEG diets than with AH (Table 5). The C24:0 in milk was found to decrease significantly ($P < 0.05$) when PBP was included in the diet. However, no significant differences were detected in the concentrations of short (C4:0–C10:0),

Table 3. Effect of treatments on milk yield and composition.

	Treatments				
Item	AH	PBP	PBP + PEG	SEM	*P*-value
DMI (kg/day)	1.59[a]	1.43[b]	1.61[a]	0.034	0.02
Milk composition (%)					
Fat	2.28	2.87	3.44	0.403	0.21
Protein	2.89	2.55	2.57	0.211	0.43
Lactose	4.55	4.35	4.16	0.148	0.27
Total solid	10.68	10.73	11.14	0.604	0.86
Solids-nonfat	8.39	7.85	7.70	0.249	0.19
Yield (g/day)					
Milk	1221	1218	1198	39.924	0.36
4%FCM	912	995	1096	77.669	0.34
Fat	27.93	34.62	37.15	4.454	0.36
Protein	35.60	30.59	30.81	2.776	0.38
Lactose	56.10	51.83	50.15	2.643	0.32

AH = alfalfa hay, PBP = pistachio by-product, PBP + PEG = pistachio by-product + PEG, 4%, FCM = fat-corrected milk for 4%, DMI = dry matter intake, SEM = standard error of the difference of least square means.
[a,b]Values in the same row without a common superscript letter are significantly different ($P < 0.05$).

Table 4. Effect of treatments on milk FAs composition.

	Treatments				
Item	AH	PBP	PBP + PEG	SEM	*P*-value
Fatty acids (g/100 g of total FAs)					
C4:0	2.94	1.28	2.17	0.323	0.09
C6:0	3.57	2.22	2.47	0.278	0.13
C8:0	4.11	2.79	2.96	0.502	0.30
C10:0	10.99	8.90	7.11	1.422	0.35
C11:0	0.22	0.13	0.26	0.111	0.64
C12:0	3.91	3.89	2.99	0.914	0.75
C13:0	0.09	0.24	0.05	0.103	0.51
C14:0	7.82	8.13	7.97	0.766	0.96
C14:1, cis-9	0.51	0.38	0.44	0.058	0.29
C15:0	0.87	0.86	0.90	0.056	0.88
C15:1, cis-9	0.26	0.26	0.29	0.042	0.78
C16:0	18.51[b]	24.08[a]	23.63[a]	0.501	0.03
C16:1, cis-9	0.91	0.99	1.40	0.177	0.33
C17:0	0.98	0.79	0.88	0.089	0.46
C17:1, cis-9	0.25	0.12	0.21	0.071	0.52
C18:0	2.69	2.59	2.89	0.721	0.96
C18:1 total trans	13.23[b]	18.76[a]	16.84[a]	0.385	0.02
C18:1, cis-9	17.22	17.66	17.66	1.062	0.98
C18:2, cis-9, cis-12 (n-6)	1.85	1.52	1.90	0.341	0.73
C18:3, cis-9, cis-12, cis-15 (n-3)	1.31	1.29	1.18	0.066	0.38
C20:0	0.92	0.31	0.29	0.287	0.39
C22:0	0.31	0.21	0.23	0.032	0.22
C22:1 (n-9)	0.44	0.29	0.29	0.104	0.57
C24:0	0.35[a]	0.23[b]	0.26[b]	0.051	0.03

AH = alfalfa hay, PBP = pistachio by-product, PBP + PEG = pistachio by-product + PEG, SEM = standard error of the difference of least square means.
[a,b]Values in the same row without a common superscript letter are significantly different ($P < 0.05$).

Table 5. Effect of treatments on milk FAs (g/100 g of total FAs).

Items	Treatments			SEM	*P*-value
	AH	PBP	PBP + PEG		
SFA	58.15	56.36	54.98	3.734	0.73
MUFA	38.61	40.60	41.91	2.431	0.68
PUFA	5.54	4.28	5.25	0.512	0.37
TFA	15.61[b]	20.23[a]	19.03[a]	0.476	0.04
SCFA	17.77	15.29	14.97	0.619	0.25
MCFA	34.08	39.73	38.72	1.211	0.14
LCFA	44.11	44.98	46.31	3.262	0.89

AH = alfalfa hay, PBP = pistachio by-product, PBP + PEG = pistachio by-product + PEG, SFA (saturated FAs) = $C_{4:0}+C_{6:0}+C_{8:0}+C_{10:0}+C_{11:0}+C_{12:0}+C_{14:0}+C_{15:0}+C_{16:0}+C_{17:0}+C_{18:0}+C_{20:0}$ $C_{22:0}+C_{24:0}$, MUFA (monounsaturated FA) = $C_{14:1}+C_{15:1}+C_{16:1}+C_{17:1}+C_{18:1\ cis}+C_{18:1\ trnas}+$ $C_{20:1}+C_{22:1}+C_{24:1}$, PUFA (polyunsaturated FA) = $C_{18:2\ cis}+C_{18:2\ trnas}+$ $C_{18:3}$, TFA (trans FAs) = $C_{18:1\ trnas}+C_{18:2\ trnas}$. SCFA = short-chain FA (C4:0 to C11:0), MCFA = medium-chain FA (C12:0 to C17:0), LCFA = long-chain FA ($\geq$C18:0), SEM = standard error of the difference of least square means.
[a,b]Values in the same row without a common superscript letter are significantly different ($P < 0.05$).

medium (C12:0–C16:1), and long ($\geq$C18:0) chain fatty acids among the treatments (Table 5). Rumen ammonia concentration decreased ($P < 0.01$) for treatments with PBP and ruminal pH tended to increase ($P < 0.09$) with PBP + PEG, as compared to other treatments (Table 6). The data for blood metabolites of the experimental goats are presented in Table 6. There were no significant differences among the treatments for cholesterol, triglyceride, BUN, total protein, albumin, and glucose concentration in the blood of dairy goats (Table 6).

Table 6. Effects of treatments on rumen parameters and blood metabolites.

Item	Treatment			SEM	*P*-value
	AH	PBP	PBP + PEG		
Ruminal parameters					
Ruminal fluid pH	6.50	6.46	6.68	0.069	0.09
Ruminal NH3-N (mg/dl)	22.92[a]	18.26[b]	20.97[a]	0.668	0.003
Blood parameters					
Glucose (mg/dl)	63.8	60.0	61.0	2.054	0.39
Triglyceride (mg/dl)	39.2	41.3	40.0	9.438	0.98
Cholesterol (mg/dl)	119.0	105.8	115.3	12.222	0.56
Albumin (g/L)	29.2	29.5	25.3	1.692	0.18
Total protein (g/L)	70.0	78.3	77.8	4.381	0.14
BUN (mg/dl)	25.1	23.5	21.3	2.911	0.67

AH = alfalfa hay, PBP = pistachio by-product, PBP + PEG = pistachio by-product + PEG, BUN: blood urea nitrogen, SEM = standard error of the difference of least square means.
[a,b]Values in the same row without a common superscript letter are significantly different ($P < 0.05$).

4. Discussion

In this study, DMI was found to decrease with inclusion of 30% PBP, which is consistent with the results reported by Shakeri and Fazaeli (2007), who observed that inclusion of 30% PBP in the diet of growing lambs decreased DMI. In their study of growing lambs, Norouzian et al. (2011), however, found no effect of inclusion of 30% PBP on DMI. Studies of early lactation dairy cows have shown no effect on DMI when 15% PBP (ensiled or dried) was included in the diet (Bohluli et al. 2009; Rezaeenia et al. 2012). The higher DMI observed in goats fed PBP + PEG than in those fed PBP in our study indicates that PEG might reduce the adverse effect of phenolic compounds in PBP on DMI. Previous studies have shown supplemental PEG to increase DMI in sheep and goats fed tannin-rich diets (Silanikove et al. 1994; Villalba et al. 2002). Silanikove et al. (1996) found that PEG supplementation increased DMI in goats fed diets including tannin-containing leaves. An inconsistency is observed among the results reported in the literature on the impacts of tannin consumption on milk yield and composition. Our finding that inclusion of 30% PBP in the diet had no effects on milk yield and composition is consistent with the results reported by Vahmani and Naserian (2005) who observed that inclusion of 14% PBP in the diet of dairy goats altered neither milk production nor milk composition. Similar effects on milk yield and composition due to the inclusion of 15% PBP have been reported by Bohluli et al. (2009) for lactating dairy cows. Dschaak et al. (2011) also reported no changes in the milk yield and composition of lactating dairy cows due to diet supplementation with 30 g/kg DM of quebracho tannins extract. Indeed, supplemental PEG did not affect milk yield and composition as reported by Cabiddu et al. (2009). However, Woodward et al. (2000) reported a higher ($P < 0.01$) milk yield in dairy cows fed lotus compared to lotus + PEG, indicating that condensed tannins could have contributed to the increased milk yield. The results obtained in the present study on milk FA composition are similar to those of Toral et al. (2013), who reported that the inclusion of quebracho tannins in the diet supplemented with sunflower oil had no effects ($P > 0.10$) on the concentration of major classes of milk fatty acid (FA) according to the degree of saturation (i.e., SFA, MUFA, and PUFA) in dairy ewes. The lack of variation in the concentration of short- and medium-chain FAs in milk fat suggests that the dietary treatments had no effect on the synthesis of FAs de novo in the mammary gland. Previous studies had shown that tannins (Dschaak

et al. 2011) and fish oil could profitably modify the FAs in milk (Whitlock et al. 2006) and in meat (Moreno-Indias et al. 2012). We would have expected to find greater concentrations of TFAs in the milk of goats fed 30% PBP (contacting a phenolic component and tannins) than those fed AH in all the diets containing fish oil. In our study, the inclusion of 30% PBP in the diets of lactating goats, containing fish oil was more effective for enhancing trans-C18:1 in milk fat than AH. The higher TFA content in the milk fat obtained for goats fed 30% PBP diets than the corresponding value obtained for those fed AH might indicate that biohydrogenation of PUFA was probably less complete when 30% PBP was used in the diets. This result could be partly attributed to the fact that the phenolic compounds of PBP probably have an inhibitory effect on the last step of ruminal FA biohydrogenation. However, reports on the impact of plants containing tannins on milk FA composition are inconsistent. Toral et al. (2013) reported that addition of 10 g/kg DM of quebracho tannins extract increased the C18:1 trans-10 content in the milk fat of dairy ewes. TFA isomers were not evaluated in the current study, due to technical limitations in the analysis procedure. Previous experiments have shown a variety of responses in ruminal pH to the inclusion of PBP in diets. Consistent with our findings, some previous reports have demonstrated no effects on ruminal pH by feeding PBP (Bohluli et al. 2009; Gholizadeh et al. 2010; Rezaeenia et al. 2012). This is while Ghasemi et al. (2012) reported that ruminal pH increased ($P < 0.01$) in Baluchi male lambs as a result of including PBP by up to 40% of their diets DM. It is a point of general agreement that tannins mainly change the ruminal fermentation pattern and reduce rumen fluid ammonia-N concentration due to the reduced ruminal degradation of protein (Min et al. 2001; Ghasemi et al. 2012). The results in our study are consistent with those of Ghasemi et al. (2012), who obtained lower ruminal ammonia-N concentrations in sheep fed 40% PBP than those fed the control diet. Priolo et al. (2000) reported that inclusion of 40 g of PEG/kg diet of tannin-fed sheep resulted in an increase in ruminal ammonia-N concentration. In agreement with these findings, in our trial, there was a higher concentration of rumen ammonia in PEG treatment, which is a clear indication of tannin deactivation. Moreover, we found that inclusion of 30% PBP in the diets of dairy goats did not affect blood metabolites. This finding agrees with those reported by Rezaeenia et al. (2012) who reported that inclusion of 15% PBPS (5.5% DM, tannins) in the diet of early lactation dairy cows had no effects on their serum glucose, BUN, and cholesterol. Similar results were reported by Bohluli et al. (2009) for serum glucose and BUN in early lactation dairy cows. Finally, Gholizadeh et al. (2010) reported that inclusion of 10% PBP in the diet of dairy cows had no effects on their blood cholesterol, BUN, triglyceride, and glucose.

5. Conclusion

The present study revealed that 30% PBP could be used as the dietary forage in the diet of dairy goats without interfering with either milk yield or milk composition. It was also found that replacement of PBP for AH would decrease rumen ammonia concentrations. Using the experimental diets in this study, the concentrations of the major classes of FAs in milk (i.e., saturated, monounsaturated, and polyunsaturated, short, medium, and long-chain FAs) remained in the same range. However, inclusion of 30% PBP in the diet of dairy goats increased the concentration of trans-C18 FAs in milk fat.

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