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Pomegranate seed pulp, pistachio hulls, and tomato pomace as replacement of wheat bran increased milk conjugated linoleic acid concentrations without adverse effects on ruminal fermentation and performance of Saanen dairy goats

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ABSTRACT

The study compared three underused agro-industrial by-products which were pomegranate seed pulp (PSP), pistachio hulls (PH) and tomato pomace (TP) available in dry areas with respect to their potentiality influence on ruminal fermentation, performance and milk fatty acid (FA) profile of dairy goats. Eight multiparous lactating Saanen goats were randomly assigned to a 4 × 4 Latin square design with 4 dietary treatments over 21-day periods. The dietary treatments were: control diet (CON), and diets containing either PSP (120 g/kg DM), PH (240 g/kg DM), or TP (240 g/kg DM), substituting for wheat bran of the control diet. All diets were kept isoenergetic and isonitrogenous with a forage to concentrate ratio of 45:55 (DM basis). The most abundant FA in the lipids of PSP and TP were *c*9,*t*11,*c*13-18:3 and *c*9,*c*12-18:2, respectively, while PH was rich in *c*9-C18:1 and phenolic compounds. No consistent treatment effects were observed on DM intake, milk yield, milk fat, protein, and lactose yields. Pomegranate seed pulp increased ($P < 0.01$) milk fat concentration compared with CON and PH diets and protein concentration of the milk samples obtained from animals fed by PH diet was highest among the treatments. There was no diet effect on ruminal pH, while rumen ammonia-N concentrations, volatile fatty acid concentrations and, to a lesser extent, molar proportion of acetate were decreased following PH diet feeding. Blood cholesterol concentration increased ($P < 0.01$) with PSP and TP diets. The blood urea N concentration decreased ($P < 0.05$) when PH diet was fed. Feeding TP diet decreased ($P < 0.01$) 16:0 and tended ($P < 0.10$) to increase *c*9-18:1 proportion in milk fat in comparison to the other diets. Inclusion of all by-products increased ($P < 0.01$) *t*11-18:1 (2-fold) and total conjugated linoleic acids (CLA, 5 to 6-fold) in milk fat compared to CON diet. In addition, concentrations of *c*9,*c*12,*c*15-18:3 and total polyunsaturated FA (PUFA) in milk fat component were highest ($P < 0.01$) in the milk samples of animals fed by PSP diet.

Abbreviations: ADF, acid detergent fiber expressed inclusive of residual ash; BUN, blood urea nitrogen; BW, body weight; CLA, conjugated linoleic acids; CON, control diet; CP, crude protein; CT, condensed tannin; DM, dry matter; DIM, days in milk; DMI, DM intake; EE, ether extract; FA, fatty acid; FAME, fatty acid methyl esters; MUFA, mono unsaturated fatty acid; NDF, neutral detergent fiber expressed inclusive of residual ash; NFC, non-fiber carbohydrates; OM, organic matter; PH, pistachio hulls; PSP, pomegranate seed pulp; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; TP, tomato pomace; VFA, volatile fatty acid.

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These findings indicate that all 3 by-products can be fed instead of wheat bran to lactating goats without adverse effects on their performance as well as ruminal fermentation. Based on the positive changes in milk FA profile, PSP was superior to the PH and TP by-products, it also promoted omega-3 FA *c*9,*c*12,*c*15-18:3 in milk.

1. Introduction

Large amounts of by-products are produced following industrial processing of pomegranate, pistachio and tomato in Iran, in forms of pulp, hulls, and pomace, respectively. Facing high feed costs and scarcities for animal nutrition, it is beneficial to promote these agro-industrial by-products as ruminant feeds. However, they differ largely in their chemical composition and fatty acid (FA) profile as well as the content of plant secondary compounds. Pomegranate seed pulp (PSP) contains large amounts of oil (6.6–19.3% DM basis) with a high level of punicic acid (*c*9,*t*11,*c*13-18:3, 65–80% of total FA) (Abbasi et al., 2008). Pistachio hulls (PH) is rich in protein (15.82% DM) and fat (6.95% DM) (Ghasemi et al., 2012) with *c*9-18:1 as the most abundant FA (Ghaffari et al., 2014b). Pistachio by-products contain considerable amounts of tannins, ranging from 34 to 101 g/kg DM (Bohluli et al., 2009). Tomato pomace (TP) is high in fiber and fat contents and its major FA is *c*9,*c*12-18:2. Such differences could determine their roles in modulating ruminal fermentation, milk composition and its FA profile. However, in comparison to agro-industrial by-products from olives, cassava, and citrus fruits, which their results were summarized by Vasta et al. (2008), these three by-products are obviously less studied.

Previous evaluations have shown that PH, TP, and PSP can be used as small ruminant feeds replacing typical forage or concentrate feeds (e.g., Ghasemi et al., 2012; Abbeddou et al., 2015; Emami et al., 2015), but this was concluded primarily based on production performance while fewer information is available in terms of their effects on milk FA, especially for PH and PSP. Moreover, to our knowledge, a comparative evaluation of these by-products is lacking. Milk FA profile determines milk physical and organoleptic properties affecting the quality of milk and dairy products as well as milk nutritional properties according to effects of specific FA on consumer health (Chilliard et al., 2003, 2007). Previous studies testing each of these by-products (Abbeddou et al., 2011; Modaresi et al., 2011; Sedighi-Vasegh et al., 2015) showed that they modulated milk FA profile toward more concentrations of FA with potential health benefits like conjugated linoleic acids (CLA) and other polyunsaturated FA (PUFA), probably due to their richness in PUFA and for PH, its tannin contents. Tannins, particularly condensed tannins (Khiaosa-Ard et al., 2009; Vasta et al., 2009; Toral et al., 2013) and *c*9,*t*11,*c*13-18:3 (Ishlak et al., 2014) can interfere with ruminal biohydrogenation by inhibiting the last step of biohydrogenation which may result in an upsurge of ruminal *t*11-18:1 availability for the endogenous synthesis of *c*9,*t*11-CLA in the mammary tissues. However, other studies (Ghaffari et al., 2014b; Abbeddou et al., 2015) failed in enhancing milk CLA and PUFA concentrations from feeding these by-products to small ruminants. The discrepancies among the studies could involve animal status, composition of diets, substitution level and approach, and supply of nutrients. Furthermore, no firm conclusions regarding benefits of these by-products as well as their superiority with respect to modulation of milk FA profile can be obtained. Therefore, there is a necessity to compare their effects on the same feeding basis.

In order to maximize the substitution levels while keeping chemical composition (energy, protein and fiber) constantly among diets, the by-products were used in place of wheat bran, as a concentrate feed, in the present experiment. Based on this strategy and because of their differences in richness of PUFA and tannin contents, we hypothesized that certain agro-industrial by-products may differently modulate milk FA profile without altering ruminal fermentation and production performance of dairy goats. The present study comparatively evaluated the potential of PSP, TP, and PH as alternative low cost feeds for lactating Saanen goats based on their effects on ruminal fermentation, milk FA profile, and production performance.

2. Materials and methods

2.1. Animals and diets

The experiment was carried out at the Research Farm of the Faculty of Agriculture, Ferdowsi University of Mashhad (Mashhad, Iran) according to the guidelines of the Iranian Council of Animal Care (1995). Eight multiparous lactating Saanen goats (43 ± 2 kg of BW, 90 ± 5 DIM; mean $\pm$ SD) were randomly assigned to a 4×4 Latin square design with 4 dietary treatments and 4 periods of 21-day (14-day of adaptation and 7 days for data collection). Dietary treatments consisted of: (1) control diet with no added by-products (**CON**), or diets containing, (2) 120 g/kg DM of **PSP**, (3) 240 g/kg DM of **PH**, or (4) 240 g/kg DM of **TP**. Wheat bran, as part of the control concentrate, was completely substituted by PH and TP in the respective diets but for PSP diet, half of wheat bran was replaced by PSP. Ingredient and chemical composition of the diets are shown in Table 1 and chemical composition and FA profile of individual by-products and wheat bran are shown in Table 2. To avoid concomitant effects of diet chemical composition on ruminal fermentation and milk FA profile, all diets were formulated to be equivalent in energy, protein and fiber contents and with a safe range of fat content for ruminant diets. Wheat bran, also a food industry by-product, was comparable to the unconventional tested by-products in terms of DM, OM, energy and