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Effects of sucrose and sunflower oil addition to diet of Saanen dairy goats on performance and milk fatty acid profile

A. Razzaghi [a,*], R. Valizadeh [a], A.A. Naserian [a], M. Danesh Mesgaran [a], L. Rashidi [b]

[a] Department of Animal Science, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran
[b] Institute of Standards and Industrial Research, Agri-Food Research Center, Fat and Oils Laboratory, Karaj, Iran

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ABSTRACT

The current study was conducted to examine the effect of dietary sucrose with or without sunflower oil on dairy goat performance, ruminal fermentation and milk fatty acid (FA) profile. Sixteen Saanen goats were assigned to the experimental diets control (basal diet without added oil and sucrose (CON), the basal diet supplemented with sunflower oil (SO, 3.7% of diet DM), sucrose (SU, 5.2% of diet DM) and sunflower oil plus sucrose (SO+SU, 3.7% and 5.2% of diet DM, respectively). Sucrose and sunflower oil replaced barley grain in the diets. Milk production and composition were analyzed on days 18, 36 and 54 on treatments, and ruminal fermentation parameters and milk FA profile on days 18 and 54. Dry matter intake, milk fat, protein and lactose concentrations were not affected by treatments. The SU increased ($P<0.1$) milk yield compared with CON whereas the SU and SO led to higher ($P<0.01$) 4% fat-corrected milk yield. The SO and SU diets increased ($P<0.1$) the milk lactose yield more than the CON diet. We observed a higher ($P<0.01$) content of ruminal acetate in the CON diet, and also higher ($P<0.05$) valerate content with the SU and SO+SU diets compared with the CON diet. Feeding SU and SO+SU tended to decrease ($P<0.05$) ruminal pH, yet goats fed SU had the highest ($P<0.01$) ruminal propionate concentration. There was no effect of diet on ruminal butyrate, isovalerate and ammonia-N concentrations. The acetate:propionate ratio substantially decreased ($P<0.05$) with the SU compared with the CON and SO+SU, and did not change with SO diet. Feeding sunflower oil increased ($P<0.01$) plasma triglyceride and cholesterol concentrations compared with feeding the CON and SU diets. The majority of fatty acids measured were not affected by inclusion of sucrose compared with the CON diet. The SO and SO+SU diets increased the proportion of total *trans*-C18:1, total CLA, and C18 family in milk fat compared to CON or SU diets. The current study implies that replacing barley grain with sucrose may improve milk yield and modify ruminal fermentation pattern in dairy goats. Moreover, sucrose did no alter ruminal fatty acid biohydrogenation pathways and following milk fatty acid composition when goats were fed with a combination of unsaturated fat and sugar.

1. Introduction

Feeding a sugar-based product can improve dry matter intake (DMI), ruminal pH, lactation performance (Penner and Oba, 2009), and change ruminal fermentation patterns; decrease ruminal ammonia-N concentration (Stensig et al., 1998; Broderick and Radloff, 2004), and increase ruminal butyrate concentration (DeFrain et al., 2006). Although none previous research reported that sugar supplement increased milk yield, several studies reported that cows fed high-sugar diets increased (Broderick et al., 2008; Khezri et al., 2009)

* Corresponding author. Tel.: +98 9125730361; fax: +98 5138796845.
E-mail address: arazzaghi88@gmail.com (A. Razzaghi).

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or tended to increase (Nombekela and Murphy, 1995) milk fat yield.

Ruminal biohydrogenation of dietary unsaturated fatty acids in ruminants results in the formation of a wide and diverse range of fatty acid intermediates that following digestion and absorption can be incorporated into milk fat including conjugated linoleic acids (CLA), which result from isomerization of *cis*-9, *cis*-12 C18:2 and are, subsequently, reduced to *trans*-C18:1 (Chilliard et al., 2007). Feeding different kinds of unsaturated fat sources to dairy goats increase the percentages of milk C18:0 and C18:1, at the expense of mainly C8 to C14 (Chilliard et al., 2003). Zened et al. (2013) observed when sunflower oil, rich in *cis*-9, *cis*-12 C18:2, was added to the diet, the ruminal pH did not change and the proportion of *trans*-11 biohydrogenation intermediates in the rumen content greatly increased, whereas the association of increasing starch level and adding *cis*-9, *cis*-12 C18:2 to the diet of cows did not change ruminal pH compared with the single addition of starch, but resulted in *trans*-10 FA increasing at the expense of *trans*-11 FA. However, accumulating evidence indicates that sugar significantly decreased the proportions of both polyunsaturated (Mullins and Bradford, 2010) and *trans*-C18:1 FA in milk fat and tended to increase milk fat yield (Penner and Oba, 2009). Incomplete biohydrogenation of unsaturated fatty acids is a main cause of decrease in milk fat synthesis (Griinari et al., 1998; Shingfield et al., 2010), but Ribeiro et al. (2005) demonstrated that biohydrogenation of unsaturated FA decreased linearly with sucrose addition in continuous culture media. These responses reflect a shift in ruminal fermentation away from propionate production, toward greater production of acetate and butyrate, increase ruminal pH and finally enhancing complete biohydrogenation of unsaturated FA (Martel et al., 2011).

However, the effect of dietary sugar on dairy goat performance, fermentation characteristics, milk FA profile and milk fat content has not been evaluated. So, the purposes of this study were: (i) test the impacts of sucrose (high level) on ruminal fermentation pattern, and milk production and composition, and (ii) evaluate the effect of association of sucrose and/or sunflower oil on milk composition, with special focus on the FA profile. To our knowledge, this is the first study that investigates inclusion of sugar with or without lipid sources in dairy goats.

2. Materials and methods

2.1. Animals and diets

The experiment was conducted at the Research Farm of the Faculty of Agriculture, Ferdowsi University of Mashhad (Iran) in 2013. Goats were cared for in accordance with the guidelines of the Iranian Council of Animal Care (1995). Sixteen multiparous Saanen goats (30 ± 3 days in lactation at the beginning of experiment, and 43 ± 3.2 kg of initial BW) were randomly assigned to the four treatment diets in a completely randomized design with four goats per treatment. The experiment lasted 54 days, including 18, 36 and 54 days of data collection. Goats were located in individual cages of 2×1.5 m with a slatted floor, water and feeding troughs. The animals were allowed continuous access to water.

Diet was provided as a TMR formulated using the small ruminant nutrition system (SRNS; Tedeschi et al., 2010) to meet the predicted energy and protein requirements (NRC, 2007). The four diets were accessible as two equal meals at 09.30 and 17.30 h and the amount of TMR offered (with mean 40:60 forage to concentrate ratio) was given to yield feed refusals between 5 and 10% of the total feed offered on an as-fed basis. Goats were fed experimental diets containing [dry matter (DM) basis]: 20% corn silage, 20% alfalfa hay, and 60% concentrate (including barley grain, soybean meal and wheat bran). Dietary treatments in this study were designated as (1) basal diet with no added sunflower oil or sucrose (CON), (2) sunflower oil (SO), (3) sucrose (SU), or (4) SU plus SO (SO+SU) added to the basal diet (Table 1). Barley grain was replaced by sucrose at 5.2% and sunflower oil at 3.7% of diet DM. The ingredients, chemical composition and FA composition of the dietary and sunflower oil are shown in Tables 1 and 2. As expected, diets had very similar contents of DM, CP, and OM (Table 1). As a direct consequence of the incorporation of oil, the SO and SO+SU diets

Table 1
Feeding ingredients and chemical composition of experimental diets.

Item	Diet[a]			
	CON	SO	SU	SU+SO
Ingredients, %				
Corn silage	20.0	20.0	20.0	20.0
Alfalfa hay	20.0	20.0	20.0	20.0
Barley grain	29.8	25.7	24.0	20.0
Wheat bran	11.9	11.4	11.3	9.9
Sucrose	–	–	5.2	5.2
Sunflower oil[b]	–	3.7	–	3.7
Soybean meal	15.6	16.5	17.0	18.1
Salt	0.5	0.5	0.5	0.5
Limestone	1.1	1.1	1.0	1.1
Minerals and Vitamins premix[c]	1.1	1.1	1.0	1.1
Chemical composition, % of DM				
DM	61.1	61.5	61.0	61.4
CP	16.1	16.2	16.1	16.0
NDF	33.9	32.7	32.1	31.0
NFC	39.3	37.2	41.5	39.3
Starch	32.5	30.6	29.9	27.7
Total ethanol-soluble carbohydrates[d]	3.9	4.0	8.7	8.8
Ether extract	2.2	5.9	2.0	5.7
Ash	10.2	9.7	10.0	10.1
Ca	0.8	0.8	0.8	0.9
P	0.4	0.4	0.4	0.4
ME, Mcal/kg of DM[e]	2.42	2.57	2.45	2.60

[a] Refers to base diets containing no additional oil (CON), 3.7% of DM of sunflower-seed oil (SO), 5.2% of DM of sucrose (SU), or 3.7% DM of sunflower seed-oil +5.2% of DM of sucrose (SO+SU).

[b] Sunflower seed-oil contained (% of total FA methyl esters): 16:0 (5.59), *cis*-16:1 (0.09), 18:0 (3.70), *cis*-18:1 (33.04), *trans*-18:2 (0.79), *cis*-18:2 (53.89), 18:3 (0.70), 20:0 (0.35), *cis*-20:1 (0.31), 22:0 (0.94), and 24:0 (0.32).

[c] Each kg of the vitamin–mineral premix contained (DM basis): vitamin A (50 000 IU), vitamin D3 (10 000 IU), vitamin E (0.1 g), calcium (196 g), phosphorus (96 g), sodium (71 g), magnesium (19 g), iron (3 g), copper (0.3 g), manganese (2 g), zinc (3 g), cobalt (0.1 g), iodine (0.1 g), selenium (0.001 g).

[d] Determined according to Hall et al. (1999), using sucrose as a standard.

[e] According to SRNS (Tedeschi et al. 2010).