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Fatty acid profile of goat milk in diets supplemented with chia seed (*Salvia hispanica* L.)

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ABSTRACT

Chia seed (*Salvia hispanica* L.) is the greatest known plant source of n-3 α-linolenic acid. The present study evaluated the effects of 3 inclusion levels of chia seed [zero (control); low, 2.7% (CLow); and high, 5.5% (CHigh)] in diets of dairy goats on milk yield and fatty acid profile. Nine Saanen dairy goats in the last third of lactation period, live weight 38 ± 8.7 kg, housed in metabolic cages, were fed iso-proteic and iso-energetic (160 g of crude protein/d and 11 MJ of metabolizable energy/d) diets. Gas chromatography was used to analyze fatty acid profile and total conjugated linoleic acid (CLA). Silver ion HPLC was used to analyze the isomeric profile of CLA. The results were subjected to variance analysis using a Latin square design repeated 3 × 3. The CHigh treatment was higher for dry matter, neutral detergent fiber, and acid detergent fiber intake compared with CLow and control diets. Digestibility was not affected by the inclusion of chia seeds. The CHigh diet improved N intake with respect to the control and CLow diet. Milk yield and chemical composition were not affected by the treatment. The milk fatty acid profile of C18:0, C18:1, C18:2, and C:20 was higher for CHigh than the other treatments. The in vitro gas production (mL of gas/g of dry matter) was lower in CHigh than the control diet. In conclusion, the addition of chia seeds at the CHigh level in dairy goat diets negatively affected in vitro rumen fermentation, but increased the milk fatty acid profile of C18:0, C18:1n-9 *cis*, and C:20, monounsaturated fatty acids, and polyunsaturated fatty acids. The total CLA content increased from 0.33 to 0.73% with the supplementation of chia to the diet, as well as the isomers *cis*-9, *trans*-11, *trans*-7, *cis*-9, *trans*-11, *cis*-13, and *trans*-12, *trans*-14.
Key words: chia seed, in vitro gas production, conjugated linoleic acid, fatty acid, dairy goat

INTRODUCTION

Dairy foods have been proven to be an excellent source of beneficial metabolites, such as CLA, n-3 and n-6 fatty acids (**FA**), antioxidants, phenols, flavonoids, and bioactive peptides (Dewhurst et al., 2006; Hilario et al., 2010; Prandini et al., 2011). However, some studies have discouraged the consumption of foods of animal origin because of the potential negative health consequences of ingesting large amounts of SFA and cholesterol. Therefore, some indices have been developed to better describe the benefits and risks of foods for human consumption, calculated from the FA profile and SFA and cholesterol content (Connor et al., 1986; Ulbricht and Southgate, 1991; Chen et al., 2004).

Goat milk is of particular economic interest in certain areas of the world. The production of this type of milk can be considered an alternative for consumers who have some type of sensitivity or allergy to dairy cow products (Luna et al., 2008) as well as being used in the preparation of cheeses. One of the most important aspects of goat milk is its high content of C6:0, C8:0, and C10:0, which compose 18% of goat milk (Adlof, 2003). Medium-chain triglycerides normally reach a percentage of 36% in goat milk in comparison with 21% in cow milk, thereby reducing the synthesis of endogenous cholesterol (Haenlein, 2004).

Different FA have potential benefits for human health, such as rumenic acid (**RA**; *cis*-9,*trans*-11 C18:2), a principal isomer of CLA, with positive effects in the prevention of cancer and atherosclerosis (Aydin, 2005). The RA content may vary due to factors such as

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Table 1. Chemical composition (means ± SD) of the ingredients used in the diet (g/kg of DM, unless otherwise indicated) of dairy goats supplemented with chia seeds

Item	Chia seeds	Corn grain	Soybean meal	Barley hay	Corn silage
Ingredient					
DM (g/kg of fresh matter)	966 ± 58	932 ± 46	923 ± 48	920 ± 41	198 ± 10
OM	972 ± 41	919 ± 37	905 ± 37	879 ± 36	939 ± 38
CP	271 ± 12	995 ± 5	443 ± 22	106 ± 4	84 ± 4
Fat	291 ± 11	271 ± 10	12 ± 0.5	10 ± 0.4	17 ± 0.8
NDF	558 ± 33	46 ± 3	70 ± 4	565 ± 22	545 ± 32
ADF	285 ± 14	23 ± 1	37 ± 2	313 ± 15	322 ± 16
ME[1] (MJ/kg of DM)	15 ± 0.6	13 ± 0.6	13 ± 0.6	10 ± 0.4	11 ± 0.5
Fatty acid composition (%)					
C16:0	6.64 ± 0.29	13.02 ± 5.72	15.80 ± 0.79	35.73 ± 1.69	19.82 ± 0.82
C18:0	3.21 ± 0.14	2.56 ± 0.12	4.41 ± 0.19	5.28 ± 0.26	3.47 ± 0.16
C18:1n-9 *cis*	6.44 ± 0.34	33.92 ± 1.69	19.40 ± 0.87	39.30 ± 1.96	19.56 ± 0.93
C18:2n-6	24.49 ± 1.47	49.54 ± 2.97	52.93 ± 2.43	19.71 ± 1.08	48.80 ± 2.73
C18:3n-3	59.20 ± 2.29	0.95 ± 0.04	7.47 ± 0.41	0.00 ± 0.0	8.35 ± 0.45

[1]Calculated by Ewing (1997).

the production systems used and the supplementation of lipids to the diet with oils or oilseed, which contain PUFA, modifying the FA profile, principally those of long-chain UFA (Chilliard et al., 2007).

Chia seed (*Salvia hispanica* L.), native to Mexico and Guatemala, has a high content of α-linolenic, linoleic, oleic, and stearic FA (Alvarez et al., 2008; Azcona et al., 2008) and could thus be an alternative in the diet of goats. The technique of in vitro gas production (Menke and Steingass, 1988; Theodorou et al., 1994) can be used to estimate the kinetics of fermentation of food in ruminant feed, in calculating its rumen degradation and interaction with rumen microorganisms. The objective of the present study was to determine the intake, digestibility, production, and composition of FA of goat milk, for goat diets supplemented with chia seed (*Salvia hispanica* L.).

MATERIALS AND METHODS

Animals, Experimental Design, and Diets

The present study was carried out at the Animal Science farm of the School of Veterinary Medicine and Animal Science of the Universidad Autonoma del Estado de México. Nine Saanen dairy goats in the last third of lactation were used, with a live weight (**LW**) of 38 ± 8.7 kg; the goats were kept in metabolic cages (1.20 × 0.80 m). Three treatments were established: a control diet with no inclusion of chia seeds, and 2 levels of inclusion of chia seeds: low (**CLow**) with 2.7% and high (**CHigh**) with 5.5.

The diets were formulated to be iso-proteic and iso-energetic (160 g of CP/d and 11 MJ of ME/d) (NRC, 2007). The chemical composition of the ingredients is shown in Table 1. The diet was based on forage (barley hay and corn silage) and concentrate (corn grain and soybean meal) supplemented with vitamins and minerals (Malta Multitec) and different inclusion levels of chia seed (Table 2). The concentrate and the proportion of feed were mixed, and the animals had free access to drinking water. Animals were fed at 0800 and 1600 h daily. The adaptation period to the diets was 15 d followed by 5 d of sampling, recording feed intake and the amount of feces, urine, and milk excreted daily. Samples of feed, feces, and urine (10%) were frozen at −20°C until analysis.

Chemical Composition of the Diets

To determine the DM content of feed, refusals and feces, samples were dried in a forced-air oven (60°C, 48 h), and subsequently ground in a Wiley mill 3 mm diameter (Arthur H. Thomas, Philadelphia, PA). Organic matter was determined by incineration (550°C for 3 h), fat, total nitrogen (AOAC International, 2005), and CP content. The NDF and ADF were determined using the ANKOM technique (Van Soest et al., 1991) with α-amylase and uncorrected for ash. Milk samples were analyzed using a MilkoScan 133B (Foss Electric, Hillerød, Denmark) to obtain the values of protein, fat, TS, and SNF. Fatty acids of the dietary components were separated by the Soxhlet method (AOAC International, 2005).

In Vitro Gas Production

The in vitro gas production technique (Theodorou et al., 1994) was used to determine the kinetics of rumen fermentation. Three rumen cannulated lactating goats were used as donors of rumen fluid (LW of 40 ± 3 kg; ±SD) and fed the control diet. Equal amounts of ru-