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Use of dry citrus pulp or soybean hulls as a replacement for corn grain in energy and nitrogen partitioning, methane emissions, and milk performance in lactating Murciano-Granadina goats

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ABSTRACT

The aim of this study was to assess the effect of substitution of dietary corn grain by dry citrus pulp or soybean hulls on energy and nitrogen partitioning, substrate oxidation, methane emission, and milk performance in dairy goats during midlactation. Twelve multiparous Murciano-Granadina goats of similar body weight (41.7 ± 2.8 kg) were split in 3 groups in an incomplete crossover design. One group of 4 goats was fed a mixed ration with 605 g/kg of dry matter of corn grain (CRG), another group replaced corn grain with dry citrus pulp (CTP), and the last with soybean hulls (SYH). The goats were allocated to individual metabolism cages. After 14 d of adaptation, feed intake, total fecal and urine output, and milk yield were recorded daily over a 5-d period. Then, gas exchange measurements were recorded by a mobile open-circuit indirect calorimetry system using a head box. Dry matter intake was similar for all 3 groups (1.53 kg/d, on average). Total replacement of the concentrate with fibrous by-products increased fiber apparent digestibility. The metabolizable energy intake was significantly greater for diet CRG than SYH (1,193 vs. 1,079 kJ/kg of $BW^{0.75}$, respectively), CTP showed an intermediate value. The heat production was higher for the fiber diet than starchy diet (908 vs. 843 kJ/kg of $BW^{0.75}$ for SYH and CRG, respectively). The efficiency of use of metabolizable energy for milk production obtained by regression was 0.59. Goats fed CTP and SYH diets produced similar CH_4 emissions (34.8 g/d, on average), significantly higher compared with goats fed the CRG diet (24.7 g/d). Goats of the 3 treatments were in negative energy balance, so the oxidation of fat was greater than for carbohydrates. No significant differences were observed for milk production (1.72 kg/d), and milk fat was significantly greater for a more fibrous diet compared with a starchy diet (6.57 vs. 4.95% in SYH and CRG, respectively).

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INTRODUCTION

In Mediterranean countries, ruminant production is limited by the poor quality and scarcity of pastures, especially during periods of drought. Consequently, farmers are forced to use cereal-based concentrates and the demand of cereals for animal feeding increases the price of concentrate. This justifies the need to develop feeding strategies based on cost-effective alternatives and local feed resources, which would increase the sustainability of livestock-production systems and improves farmers' income. Agricultural by-products may be of interest not only to reduce feed cost, but also to reduce environmental problems associated with by-product accumulation (Vasta et al., 2008).

Increasing interest in by-products has occurred as partial substitution of traditional feedstuffs in ruminant feeding has become more prevalent. From a nutritional point of view, by-products are included in the ration to supply energy and protein, but are often also characterized by high fiber content. This is the case with citrus pulp or soybean hulls, which are typically used as grain replacers. A large number of the citrus by-products feedstuffs, including citrus pulp, are suitable for inclusion in ruminant diets because of the ability of ruminants to ferment high-fiber feeds in the rumen (Grasser et al., 1995). According to FEDNA (2010), the NDF level of dry citrus pulp is intermediate (25%), between that of most concentrates and forages, and contains relatively large amounts of pectins (25%) and sugars (23%), a small amount of ADL (2%), and a very limited amount of available nitrogen (6% of CP). Soybean hulls are high in NDF (58%, high in cellulose) but low in ADL (2%) and NFC (24%).

Dietary composition affects the ruminal fermentation and, consequently, energy metabolism, CH_4 emissions, and milk composition. Methane is an undesirable end product of rumen fermentation as it represents an energy loss to the animal and because it is a major greenhouse gas. In ruminant nutrition, decreased production of CH_4 can represent an improvement in feed efficiency, because ruminants loose between 2 and 12% of the gross dietary energy in the form of CH_4 (Johnson and Johnson, 1995). Besides, ruminants contribute to global warming through N excretion from urine and feces. To reduce N excretion and improve N efficiency of ruminant, dietary levels of N and optimal balance between N and energy substrates in the diet should be targeted.

Our hypothesis was that citrus pulp and soybean hulls could replace cereal-based concentrate in goat diets without compromising energy and protein partitioning in lactating goats when mixed diets were formulated with similar amounts of energy and protein. The purpose of the present experiment was to study the effect of substitution of corn grain in the mixed diet by dry citrus pulp or soybean hulls on energy partitioning, CH_4 emissions, C and N balance, and milk performance in dairy goats during midlactation.

MATERIALS AND METHODS

Animals and Feeding

The experimental procedure was approved by the Animal Use and Care Committee of the Polytechnic University of Valencia (Spain) and followed the codes of practice for animals used in experimental works proposed by the European Union (2003). Twelve multiparous mature and nonpregnant Murciano-Granadina goats of similar BW (41.7 ± 2.8 kg) and in midlactation were randomly split into 3 groups (4 goats per treatment) in an incomplete crossover design. Treatments consisted of 3 different concentrate mixed rations (Table 1). Goats were fed daily 0.25 kg of cereal straw as forage and 1.5 kg of concentrate (forage:concentrate ratio = 14:86). The concentrate was mixed and pelleted along with the premix. One group was fed concentrate with 605 g/kg of DM of corn grain (**CRG**). The other 2 groups substituted corn grain with by-products: dry citrus pulp (**CTP**) and soybean hulls (**SYH**). Chemical composition shown in Table 1 is the whole mixed ration (forage and pelleted concentrate). The mean gross energy (**GE**) of the 3 diets was 17.6 MJ/kg of DM. The main difference among diets was the source of carbohydrates. Starch levels were 41.6, 6.4, and 1.5% (on a DM basis) for the CRG, CTP, and SYH diets, respectively. Neutral detergent fiber and neutral detergent soluble fiber (**NDSF**) values were 30.1 and 8.5% (respectively, DM basis) for CRG, 30.1 and 24.1% (respectively, DM basis) for CTP, and 59.0 and 17.1% (respectively, DM basis) for SYH. Mixed diets contained similar amounts of CP (15.8%, DM basis). Nutrient requirements followed the recommendation of Lachica and Aguilera (2003) and Calsamiglia et al. (2009) for goats in lactation. Apparent total tract digestibility, gas exchange, energy partitioning, C and N balance, oxidation of nutrients, and milk composition and yield were determined. Moreover, ruminal fermentation parameters were determined in the second period of the experiment. Half the daily ration was offered at 0800 h and half at 1600 h. Goats had free access to water.

Experimental Schedule and Measurements

The experiment was conducted in an incomplete crossover design in two 31-d periods. During the adaptation, goats were fed experimental diets in pens for 7 d and then allocated in individual metabolism cages at thermoneutrality (20–23°C determined by a Hobo probe, Onset Data Loggers, Cape Cod, MA) for another 7 d. Next, data on the feed offered and refused

Table 1. Ingredients and chemical composition of the diets

	Diet[1]		
Item	CRG	CTP	SYH
Ingredient, g/kg of DM			
Barley straw (as a forage)	150.0	150.0	150.0
Corn	605.2	—	—
Soy hulls	—	—	610.0
Citrus pulp	—	605.2	—
Soy meal (44% CP)	202.4	221.7	173.9
Calcium carbonate	21.6	4.0	22.9
Salt	10.8	9.1	25.5
Bypass fat[2]	5.0	5.0	12.7
Premix[3]	5.0	5.0	5.0
Chemical composition, % of DM (unless otherwise noted)			
DM, %	88.36	88.41	90.15
OM	92.80	91.96	89.28
CP	16.66	15.80	14.79
Ether extract	2.66	2.10	2.03
NDF	30.11	30.08	58.97
ADF	8.55	16.69	37.55
Lignin	0.44	0.93	1.22
NDSF[4]	8.51	24.09	17.07
NFC[5]	45.30	43.98	13.50
Starch	41.63	6.36	1.45
Sugar + pectin[6]	1.75	37.63	12.05
Gross energy, MJ/kg of DM	18.00	17.56	17.21

[1]CRG = corn grain diet; CTP = citrus pulp diet; SYH = soy hulls diet.

[2]Bypass fat of palm FA distillate. Provided by Norel Animal Nutrition (Norel S.A., Madrid, Spain).

[3]Provided by Nacoop S.A. (Madrid, Spain). Premix composition: 40 mg of Se/kg, 250 mg of I/kg, 80 mg of Co/kg, 3,000 mg of Cu/kg, 6,000 mg of Fe/kg, 23,400 mg of Zn/kg, 29,000 mg of Mn/kg, 60,000 mg of S/kg, 60,000 mg of Mg/kg, 2,000,000 IU of vitamin A/kg, 400,000 IU of vitamin D_3/kg, 2,000 mg of vitamin E/kg, 10,000 mg of nicotinic acid/kg, and 20,300 mg of choline/kg.

[4]NDSF = neutral detergent-soluble fiber.

[5]NFC = 100 − (NDF + ash + CP + ether extract).

[6]Sugars + pectins = NFC − starch.