Effects of partial replacement of concentrate with feed blocks on nutrient utilization, microbial N flow, and milk yield and composition in goats

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ABSTRACT

Two experiments were carried out to evaluate the effect of partial replacement of concentrate with 2 types of feed blocks (FB) on rumen protozoa numbers, nutrient utilization, microbial N flow to the duodenum, and milk yield and composition in goats. The concentrate included oat, corn grain, barley, soybean meal, salt, and vitamin-mineral mixture. The FB (types I and II) were composed of crude 2-stage olive cake (120 or 100 g/kg), fava beans (0 or 400 g/kg), barley (320 or 200 g/kg), beet molasses (220 or 100 g/kg), sunflower meal (180 or 0 g/kg), quicklime (70 or 90 g/kg), salt (60 g/kg), urea (0 or 20 g/kg), and vitamin-mineral mixture (30 g/kg). In experiment 1, 6 adult, dry, nonpregnant, rumen-fistulated Granadina goats (46.9 ± 2.15 kg of BW) were used and 3 trials were carried out. In each trial, 2 goats were randomly assigned to receive 600 g of alfalfa hay and 400 g of concentrate (diet AC), 600 g of alfalfa hay, 200 g of concentrate, and FB I (diet ACBI), or 600 g of alfalfa hay, 200 g of concentrate, and FB II (diet ACBII) with 6 replications per diet. The FB were supplied ad libitum. The ratio of purine bases to N was higher in solid- and liquid-associated bacteria for FB goats than for AC goats. In experiment 2, 18 Granadina goats (39.6 ± 1.89 kg of BW) in the middle of the third lactation were used, and 3 trials were carried out by following a 3×3 Latin square experimental design. In every trial, 6 animals randomly received 1.0 kg of alfalfa hay supplemented with 1.0 kg of concentrate (diet AC) or 0.5 kg of concentrate and FB I and II (diets ACBI and ACBII) with 18 replications per diet. The FB were supplied ad libitum. The intakes of organic matter and fat were higher with the AC diet than with the FB diets. The intake of acid detergent fiber was higher for FB-containing diets than for the AC diet. The neutral detergent fiber di-

gestibility of FB diets was higher than that of the AC diet. Energy intake was higher for diets AC and ACBII than for ACBI. Microbial N flow was affected by diet. Milk yield was higher in goats fed the AC diet than in those receiving the FB diets. Conjugated linoleic acid content was higher in milk from FB than in milk from AC goats. Our study suggests that FB type II based on local ingredients could be used advantageously to reduce half of the amount of concentrate without detrimental effects on nutrient utilization, N value of the diet, and milk composition. The decrease of milk yield with ACBII compared with that obtained with the AC diet could be compensated by better quality of milk, decreased cost of feeding, and environmental advantage derived of including by-products in FB.

Key words: concentrate feed, feed blocks, goat milk yield and composition, microbial N flow

INTRODUCTION

Livestock production in arid and semiarid areas is constrained by the scarcity and high prices of feedstuffs, mainly concentrate feeds. The use of conventional feedstuffs for small ruminants in Mediterranean production systems is often inefficient and expensive (Al Jassim et al., 1997). Dairy goat farming is of relevant economic, environmental, and sociological importance in the Mediterranean basin (Rancourt et al., 2006) with an increasing demand for gourmet cheeses, yogurt, and milk from sheep and goats (Haenlein, 2001). Milk and dairy products from goats are important foods for man, especially for people with food allergies or for those living in dry areas where cow's milk is scarce (Park, 2006; Sanz Ceballos et al., 2009). The increased demand for animal products in developing countries (Delgado et al., 1999) involves, therefore, an increased demand for cereals for animal feed that competes with that for human consumption. In addition, there is increasing use of concentrate feeds in biofuel production, resulting in an important increase of their prices (FAO, 2006). Therefore, the development of feeding strategies based

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on cost-effective alternative and local feed resources would guarantee the sustainability of livestock production systems and improves farmers' incomes. Feed blocks (**FB**), a solidified mixture of unconventional feeds such as agro-industrial by-products, urea, binder, salt, and mineral and vitamin supplement (Ben Salem and Nefzaoui, 2003) may help to overcome the situation and could reduce the proportion of concentrate feeds in dairy goat diets. Local legume seeds or by-products such as sunflower meal could replace soybean meal. The olive oil industry generates, in addition to oil, high quantities of by-products such as crude 2-stage olive cake (**CTSOC**) composed of olive pulp, skin, and stones as well as water (Hermoso et al., 1995). Production of CTSOC in southern Spain is estimated to be 2,000,000 t/yr (Molina-Alcaide and Yáñez-Ruiz, 2008) with high pollutant potential due, in part, to its high moisture content. Additionally, FB utilization could decrease the feeding cost.

The influence of diet on milk production may depend more on ruminal fermentation balance and end products than on the digestible or metabolizable energy content (Sanz-Sampelayo et al., 1998). It is well documented that diet composition affects ruminal fermentation, and hence milk composition (Morand-Fehr et al., 1991). Lipid composition is one of the most important factors determining the technological, nutritional, and health quality of goat's milk (Chilliard et al., 2003). Differences in protozoa distribution could explain different fatty acid profiles (Chalupa and Kutches, 1968). Devillard et al. (2004) observed higher concentrations of vaccenic acid (**VA**) than rumenic acid in the ciliates. Because protozoa represent approximately half of the rumen biomass (Jouany, 1995), ciliated protozoa constitute a major pool of unsaturated fatty acids in the rumen. Although biohydrogenation in the rumen has been considered only in terms of bacterial activity, recent observations suggest that rumen protozoa may also play an important role because they are higher in VA and conjugated linoleic acid (**CLA**) than bacteria (Devillard et al., 2006). Protozoa accounted for 30 to 43% of CLA and 40% of VA reaching the duodenum (Yáñez-Ruiz et al., 2006).

Our hypothesis was that the replacement of concentrate in dairy goat feeding with FB, which allow a balanced, synchronous, and fractionated supply of essential nutrients (i.e., energy, nitrogen and minerals), would not compromise nutrient utilization, rumen fermentation, or milk yield and composition. The concentrate included cereals (800 g/kg) and soybean meal (160 g/kg), and FB (types I and II) were composed of barley (320 or 200 g/kg) and local sources of N (180 g/kg sunflower meal or 400 g/kg fava beans) and by-

products such as CTSOC and beet molasses. The effect of diets on rumen protozoa numbers, nutrient utilization, microbial N flow to the duodenum, and milk yield and composition were evaluated in goats.

MATERIALS AND METHODS

All management and experimental procedures involving animals were carried out by trained personnel in strict accordance with the Spanish guidelines (Act No. 1201/2005 of 10 October 2005) for experimental animal protection.

Diets

Three experimental diets were formulated with alfalfa hay plus concentrate (diet **AC**) and alfalfa hay plus concentrate and type I and II FB (diets **ACBI** and **ACBII**). Ingredient composition of concentrate and FB is shown in Table 1. The ingredients of concentrate and FB solid ingredients were ground (2 mm) and mixed in a horizontal mixer (P. Prat model C, Sabadell, Spain). The concentrate was granulated in a rotating pelletizer (Vector CPM Europe, Andrijftechniek B.V., Rotterdam, the Netherlands) by spraying it with water. Block manufacturing followed the protocol of Ben Salem and Nefzaoui (2003), with some modifications. Solid ingredients were mixed with a liquid mixture composed of water, quicklime, salt, beet molasses, urea, and CTSOC and then heavily packed in aluminum molds. Compacted blocks were removed from the molds, air-dried at room temperature, and stored until distribution to the animals.

Experiment 1

Six adult, dry, nonpregnant, rumen-fistulated Granadina goats (45.6 ± 2.5 kg of BW) were used. Animals were placed in individual boxes and had free access to water. Animals were fed (once a day) 600 g of alfalfa hay and 400 g of concentrate (diet **AC**) or 600 g of alfalfa hay, 200 g of concentrate, and feed block I (diet **ACBI**) or feed block II (diet **ACBII**). Feed blocks were supplied ad libitum, resulting in average intakes of 180 ± 79.7 and 291 ± 60.9 g of fresh matter/animal per day for feed blocks I and II, respectively. No refusals were observed for hay or concentrate. Three trials were carried out and experimental treatments were assigned randomly within each trial, with 6 replications for each diet. Each trial consisted of 25 d for adaptation and 4 d for sampling. Individual intakes of diet ingredients were registered throughout the trial. On d 26 and 28, 100-mL samples of rumen content were obtained from each

animal at 0, 2, 4, and 6 h after feeding and strained through 2 layers of cheesecloth. A 5-mL aliquot of strained liquid was prepared for protozoa counting, following the procedure described by Dehority (1984). Twenty fields per aliquot were counted, and total protozoa numbers and holotrichia and entodiniomorphida proportions were recorded. On d 27 and 29, 500-mL samples of rumen contents were obtained from each animal 2 h after feeding for isolation of solid- (**SAB**) and liquid- (**LAB**) associated bacteria pellets. For SAB and LAB isolation, rumen contents were strained through 4 layers of cheesecloth. The solid residue was washed with cold (4°C) NaCl solution (9 g/L) and strained again through 4 layers of cheesecloth. The final filtrate was used to isolate LAB by differential centrifugation ($800 \times g$ for 10 min at 4°C, and supernatant fraction at $27,800 \times g$ for 10 min at 4°C). The solid fraction was resuspended in cold (4°C) NaCl solution (2.5 mL/g of solid), subjected to vigorous mechanical pummeling between 2 metal plates (Masticator, IUL Instruments GmbH, Königswinter, Germany) for 5 min to detach bacteria from the feed particles (Michalet-Doreau and Ould-Bah, 1992), and strained through 4 layers of cheesecloth. The solid residue was washed with cold (4°C) NaCl solution (9 g/L) and strained, and the filtrate was added to that obtained previously. The final mixed filtrate was differentially centrifuged as described for LAB to isolate the SAB pellet. All bacterial pellets were lyophilized and ground to a fine powder with a mortar and pestle before analyzed for DM, N, and purine bases (**PB**).

Experiment 2

Eighteen Granadina goats (39.6 ± 1.89 kg of BW) in the middle of the third lactation were used. Animals were separated into 3 homogeneous weight and milk yield groups. Three trials were carried out by following a 3×3 Latin square experimental design. In each trial, 6 animals received randomly 1.0 kg of alfalfa hay and 1.0 kg of concentrate (diet AC) per animal and day; 1.0 kg of alfalfa hay, 0.5 kg of concentrate, and FB I or II (diets ACBI and ACBII) per animal and day with 18 replications per treatment. All the diet ingredients were supplied once a day. The specific N and energy requirements of this species and breed (Aguilera et al., 1990) were considered in the dietary formulation. Amounts of alfalfa hay and concentrate supplied to the animals fed diet AC were sufficient to allow daily milk production of up to 2 kg per goat. Blocks were fed ad libitum.

After 25 d of adaptation to the corresponding experimental diet, during which animals were individually kept in boxes with free access to food and water, animals were moved to individual metabolism crates.

Table 1. Ingredients composition (g/kg, as-fed basis) of concentrate and feed blocks

Ingredient	Concentrate	Feed block I	Feed block II
Oat	350		
Corn grain	350		
Crude two-stage olive cake		120	100
Fava beans			400
Barley grain	100	320	200
Soybean meal	160		
Beet molasses		220	100
Sunflower meal		180	
Quicklime		70	90
NaCl	10	60	60
Urea			20
Vitamin-mineral mixture ¹	30	30	30

¹Formulated (per kilogram) with NaCl, 277 g; ashes from the two-stage dried olive cake, 270 g; $(\text{PO}_4)_2\text{H}_4\text{Ca}$, 250 g; MgSO_4 , 200 g; CuO, 184 mg; I, 25 mg; CoO, 8.5 mg; Se, 4 mg; ZnO, 2.28 mg; and 83,500 and 16,700 IU of vitamins A and D, respectively.

After 3 d of adaptation to metabolism crates, total feces and urine production and feed refusals were collected daily in the morning from each animal for 7 d and then weighed. Aliquots representing 10, 20, and 30% of daily production, respectively, were stored at -20°C for chemical analyses. Urine was collected in buckets with 10% H_2SO_4 (vol/vol) to maintain pH below 3 and avoid any N loss. Samples of feed offered were also collected daily, pooled, and stored at -20°C . The nutrient apparent digestibility of diets was determined from measurement of nutrient intakes and losses in feces. The N and energy balances were obtained taking into account the urinary and fecal losses of N and energy and estimated methane energy losses. The amounts of N and energy derived to milk were also considered. During the last 5 d of the sampling period, 100-mL aliquots of urine were taken for analysis of purine derivative (**PD**) and creatinine concentrations. The urine density was measured as well. Every day during the adaptation and sampling periods, goats were hand-milked once a day before feeding and milk yield recorded. Every sampling day, milk density was measured and aliquots were stored at -30°C without preservatives until analyzed.

Chemical Analyses

Dry matter (AOAC, 2005; method 934.01), ash (AOAC, 2005; method 942.05), ether extract (AOAC, 2005; method 920.39), and N (AOAC, 2005; method 984.13) in samples of supplied and refused diets, feces, and urine were determined according to AOAC (2005) methods. The N values of feeds, refusals, feces, and urine, determined by following the Kjeldahl procedure, were converted to CP by multiplying by a factor of 6.25. The analyses of NDF and ADF were carried out according to Van Soest et al. (1991) using an Ankom²²⁰ Fiber Analyzer unit (Ankom Technology Corp., Mace-

don, NY). Amylase was not used in the analysis of NDF, and both NDF and ADF were expressed exclusive of residual ash. Lignin was determined by solubilization of cellulose with 72% sulfuric acid. The fat content in feedstuffs and feces was measured by extraction with petroleum ether (boiling point, 40 to 60°C). The energy content of the samples was determined by using an adiabatic bomb calorimeter (model 1356, Parr Instruments Co., Moline, IL).

The PB concentration in feeds and SAB and LAB pellets isolated from the rumen and creatinine and PD in urine were determined according to Balcells et al. (1992) using HPLC, which consisted of a multisolvent delivery system (model 510; Waters, Milford, MA), an injector (WatersTM 717 plus Autosampler, Waters), a multiwavelength detector (model 481; Lambda-Max, LC Spectrophotometer, Waters, set to 205 nm), and a double 4.0 mm × 250 mm C18 ODS-2 analytical column (Waters Spherisorb). The PB and PD were quantified by peak integration using the Waters HPLC systems software Millennium32.

Milk total solids content was determined by lyophilization. The total N content was determined by following the Kjeldahl procedure. Nonprotein N was analyzed in samples of milk filtrate after precipitation with 12% (wt/vol) TCA. Noncasein N was determined in milk filtrate after precipitation with 10% (wt/vol) acetic acid at a pH of 4.1 (Recio et al., 1997). Values of N were converted to the corresponding protein by multiplying by 6.38. The milk fat content was measured by following the Gerber method (Pearson, 1976).

To determine the fatty acid (FA) composition of feed and milk fat, the fatty acid methyl esters were separated on an autosystem gas chromatograph (model 10205, Perkin-Elmer Corp., Norwalk, CT) with a Supelco SP-2560 capillary column (100 m × 0.25 mm i.d.; Supelco, Bellefonte, PA) provided with a 5-m silica pre-column and equipped with a flame-ionization detector. The temperature was programmed at 70°C for 1 min, then increased from 70 to 100°C at the rate of 5°C/min, maintained for 2 min, increased from 100 to 175°C at 10°C/min, maintained for 34 min, increased from 175 to 225°C at a rate of 4°C/min, and maintained for 7 min. The carrier gas was N₂ (1 mL/min). Injector and detector temperatures were 250 and 255°C, respectively. Peak for individual fatty acids were identified using pure methyl ester standards (Supelco). Standards for conjugated linoleic acid (CLA) isomers (*cis*-9,*trans*-11 and *trans*-10,*cis*-12) were obtained from Matreya Inc. (Pleasant Gap, PA). Peak areas for individual FA were corrected for recovery using a butter-oil reference standard (CRM 164, Commission of the European Community Bureau of References, Brussels, Belgium).

Calculations and Statistical Analysis

The milk protein-N content was calculated as the difference between total and nonprotein milk N. Casein milk N content was calculated as the difference between total and noncasein milk N. The whey milk N content was calculated as the difference between milk protein and casein-N. Milk lactose was calculated as the difference between the amount of total solids and the sum of protein, fat, and total ash.

The PB daily flow was calculated as daily PD urine excretion/0.74. The 0.74 value was obtained from Mota et al. (2008) for the PB recovery rate. The microbial N flow (MNF) was estimated from PB daily flow and PB:N ratios in SAB or LAB. The efficiency of microbial N synthesis was expressed per kilogram of OM apparently fermented in the rumen, calculated as 0.65 of digestible OM intake (ARC, 1984).

The SPSS for Windows, version 14.0 (2005; SPSS Inc., Chicago, IL) was used for data entry and statistical analysis. Data from experiment 1 were analyzed by the one-way ANOVA. The model included diet as fixed effect, and period and animal were considered as random effects. Data from experiment 2 were analyzed by GLM using the repeated measures ANOVA by following a 3 × 3 Latin square design. Diet was considered as fixed effect, and period and animal were considered as random effects. When a significant effect of diet was found, post hoc comparison of means was made using the Bonferroni test. Differences were considered significant at $P < 0.05$, and $P < 0.10$ values were declared as trends and discussed.

RESULTS

The chemical composition of diet ingredients is shown in Table 2. Compared with concentrate, feed blocks were lower in energy and CP. Crude protein and energy contents were higher in FB II than in FB I.

Experiment 1

Absolute holotrichia values were higher for diet ACBII compared with AC or ACBI (Table 3). Figure 1 shows the effect of diet on the evolution of the rumen protozoa numbers after feeding. The PB:N ratio in SAB (Table 3) was higher ($P < 0.001$) for diet ACBI followed by ACBII, and finally the AC diet, whereas for LAB, the ratio was lower ($P < 0.001$) for diet AC than for the diets including FB.

Experiment 2

The DM intake for alfalfa hay (Table 4) was lower ($P = 0.008$) in goats receiving diet AC than in those fed

Table 2. Chemical composition (g/kg, DM basis) of diet ingredients

Item	Alfalfa hay	Concentrate	Feed block I	Feed block II
DM, g/kg of fresh matter	864	860	790	760
OM	894	901	731	740
CP	175	159	104	132
NDF	491	214	167	127
ADF	331	58.5	80.3	24.0
Acid detergent lignin	84.1	6.76	13.0	1.86
Ether extract	13.6	3.93	3.39	2.62
Gross energy, MJ/kg of DM	16.9	16.7	12.5	13.3
Purine bases, $\mu\text{mol/g}$ of DM				
Adenine	7.80	10.0	15.4	14.5
Guanine	9.09	3.96	3.86	3.55
Total	16.9	14.0	19.3	18.1
Fatty acids, % of fat				
C12:0	0.324	ND ¹	ND	ND
C14:0	1.42	0.292	0.249	0.230
C14:1	ND	ND	ND	0.110
C16:0	31.5	18.0	15.6	13.7
C16:1	2.50	ND	0.31	0.19
C18:0	6.81	3.06	2.62	2.32
C18:1 (9)	5.08	37.1	46.3	39.8
C18:2 (9, 12)	18.1	35.9	31.4	38.5
C18:3 (9,12,15)	ND	1.11	0.453	0.855
C18:3 (6,9,12)	31.1	1.33	2.50	2.34
C20:0	1.18	0.33	0.27	0.58
C20:1	ND	0.371	ND	ND
C20:4	ND	1.65	ND	1.01
C20:5	1.99	0.843	0.362	0.296
Medium-chain fatty acids	1.74	0.292	0.249	0.340
Monounsaturated fatty acids	7.58	37.5	46.6	40.1
Polyunsaturated fatty acids	51.2	40.8	34.7	43.0
Saturated fatty acids	41.2	21.7	18.7	16.9

¹ND = not detected.

FB diets. The OM intake for diet AC was higher ($P < 0.035$) than for diet ACBI. Fat intake was highest ($P < 0.002$) for diet AC, followed by ACBI, and finally ACBII. Intake of ADF was highest ($P < 0.016$) for diet ACBI, followed by ACBII, and finally diet AC. Fat digestibility was higher ($P < 0.007$) for diet AC than for those diets including FB. The digestibility of NDF was lower ($P < 0.039$) for diet AC than for diets including FB. Concerning ADF, digestibility differences

($P < 0.001$) were only detected between diets AC and ACBI. Milk total and protein N (Table 5) were higher ($P \leq 0.023$) for diet AC than for diets including FB. However, retained N was lower ($P = 0.050$) for diet AC than for FB-containing diets. The percentage of milk protein N in relation to the N balance was lower ($P < 0.050$) for diet ACBI than for diets AC and ACBII. The energy intake was higher ($P = 0.016$) for diets AC and ACBII than for diet ACBI. Fecal energy was similar

Table 3. Protozoa numbers ($\times 10^4/\text{mL}$) and purine bases:N ratios ($\mu\text{mol/mg}$) in solid- (SAB) and liquid- (LAB) associated bacteria in the rumen liquor of goats ($n = 18$) fed the experimental diets

Item	Diet ¹			SEM	<i>P</i> -value
	AC	ACBI	ACBII		
Entodiniomorphida	81.3	72.5	66.4	3.02	0.143
Holotrichia	2.35	1.95	3.13	0.25	0.131
Total protozoa	83.6	74.4	69.5	3.07	0.182
Purine bases:N					
SAB	0.508 ^a	0.710 ^c	0.583 ^b	0.016	<0.001
LAB	0.658 ^a	0.924 ^b	0.894 ^b	0.032	<0.001

^{a-c}Within a row, means without a common superscript letter differ ($P < 0.05$).¹AC = 600 g of alfalfa hay and 400 g of concentrate; ACBI = 600 g of alfalfa hay, 200 g of concentrate, and 180 $\pm$ 80 g of feed block I; ACBII = 600 g of alfalfa hay, 200 g of concentrate, and 291 $\pm$ 61 g of feed block II (fresh matter basis).

Figure 1. Effect of experimental diets on the evolution of the rumen protozoa numbers after feeding: ■, AC = 600 g of alfalfa hay and 400 g of concentrate; ▲, ACBI = 600 g of alfalfa hay, 200 g of concentrate, and 180 ± 80 g of feed block I; ♦, ACBII = 600 g of alfalfa hay, 200 g of concentrate, and 291 ± 61 g of feed block II (fresh matter basis). Solid curves = entodiniomorphida ($P = 0.221$; SEM = 5.08); dashed curves = holotrichia ($P = 0.626$; SEM = 0.42).

($P = 0.502$) for the 3 experimental diets. Urine energy was lower ($P = 0.043$) for diet ACBI than for the AC or ACBII diets. Milk energy was higher ($P = 0.049$) for diet AC than for diets ACBI and ACBII.

Urinary excretion of xanthine (Table 6) was affected ($P = 0.036$) by diet, with the highest values being for diet AC. The MNF was affected ($P \leq 0.045$) by diet regardless of the bacterial pellet used as reference for its estimation. Values obtained by using SAB were

higher ($P = 0.045$) for diets AC and ACBII than those obtained for diet ACBI. The pattern of diet effect was different with LAB, as MNF obtained for diet AC was higher ($P = 0.043$) than those for diets ACBI and ACBII. The efficiency of microbial protein synthesis, expressed per kilogram of OM apparently fermented in the rumen, was affected ($P \leq 0.045$) by diet. Values obtained from SAB were only different ($P = 0.036$) for diets AC and ACBI. When values were obtained by using LAB as reference bacterial pellet, the highest ($P = 0.045$) efficiency was obtained for diet AC.

Milk yield (Table 7) was higher ($P = 0.016$) in goats fed diet AC than in those receiving diets ACBI or ACBII. Higher ($P \leq 0.049$) yields of milk protein, casein, lactose, and total milk solids were obtained with diet AC compared with ACBI or ACBII. Milk fat yield was higher ($P = 0.030$) for diet AC than for ACBII.

Average proportions of C4:0, C6:0, C8:0, C10:0, medium-chain and saturated FA in milk (Table 8) were higher ($P \leq 0.046$) for diets AC and ACBI compared with diet ACBII. The proportion of VA (C18:1 *trans*-11) was higher ($P = 0.050$) for diet ACBII than for diets AC and ACBI. The proportions of rumenic (C18:2 *cis*-9, *trans*-11) and linolenic acids and total CLA were higher ($P \leq 0.033$) for diets ACBI and ACBII than for AC. The VA/CLA ratio was lower ($P = 0.045$), and the atherogenicity index was higher ($P = 0.022$) for milk from goats fed diet AC than for those receiving FB diets.

Table 4. Intake (g/d) and apparent digestibility (%) of the experimental diets nutrients in dairy goats (n = 18)

Item	Diet ¹			SEM	P-value ²
	AC	ACBI	ACBII		
Intake					
DM	1,373	1,295	1,405	51.9	0.143
Alfalfa hay	589 ^a	699 ^b	715 ^b	24.6	0.008
Concentrate	780 ^b	431 ^a	426 ^a	13.1	<0.001
Blocks	0 ^a	165 ^b	263 ^b	35.6	<0.001
OM	1,247 ^b	1,134 ^a	1,218 ^b	40.2	0.027
Fat	38.9 ^c	33.3 ^b	29.5 ^a	0.94	0.002
CP	235	212	224	7.70	0.170
NDF	469	617	563	19.1	0.207
ADF	251 ^a	338 ^c	292 ^b	9.81	0.016
Apparent digestibility					
DM	68.1	68.5	69.9	1.77	0.703
OM	70.0	67.4	70.3	1.70	0.458
Fat	80.0 ^b	70.3 ^a	71.3 ^a	1.77	0.007
CP	69.1	71.4	71.5	1.96	0.452
NDF	49.3 ^a	63.4 ^b	57.8 ^b	2.45	0.039
ADF	39.0 ^a	53.2 ^b	46.0 ^{ab}	2.48	0.001

^{a-c}Within a row, means without a common superscript letter differ ($P < 0.05$).

¹AC = 707 g of alfalfa hay and 916 g of concentrate; ACBI = 789 g of alfalfa hay, 497 g of concentrate, and 209 ± 32 g of feed block I; ACBII = 811 g of alfalfa hay, 498 g of concentrate, and 346 ± 56 g of feed block II (fresh matter basis).

²Without taking into account the AC diet, when we compared ACBI and ACBII diets, the P -value for concentrate = 0.120 (SEM = 1.86); the P -value for blocks = 0.123 (SEM = 43.6).

DISCUSSION

The shortage of cereals for animal feeding increases the price of concentrate and justifies the need to use locally available alternative feedstuffs in livestock feeding. Feed blocks may reduce the excessive use of concentrate feeds in ruminant feeding. To our knowledge, this is the first experiment dealing with the replacement value of FB for concentrate as supplements for dairy goats. Cereal's price increased from \$134/t in 2003–2004 to \$264/t in 2007–2008 (Crop Prospects and Food Situation; FAO, 2008). Taking into account the proportion of cereals in the concentrate and FB, their average intakes in the current study, and the cost of cereals, a reduction in feeding cost of 36% may be achieved with diets

containing FB compared with the control diet. The reduction in milk produced daily by goats fed FB diets was 23 and 17% for FBI and FBII, respectively.

Additionally, FB use a wide range of agro-industrial by-products in animal feeding, especially those with high moisture, thereby permitting recycling and decreasing feeding cost and increasing availability for human consumption. The inclusion of high-moisture by-products such as CTSOC (400 g of DM/kg of fresh matter; unpublished data) in ruminant diets is regarded as a challenging practice. The CTSOC could offer an additional advantage based on the presence of polyphenols (37.3 g of condensed tannins/kg of DM) and fat (100 g of ether extract/kg of DM) rich in oleic (70.1%) and linoleic (9.5%) acids (unpublished data).

Table 5. Mean values for BW, N, and energy utilization of the experimental diets (n = 18)

Item	Diet ¹			SEM	P-value
	AC	ACBI	ACBII		
BW, kg	38.3	39.0	39.5	0.523	0.626
BW ^{0.75}	15.4	15.6	15.7	0.154	0.636
N utilization, g/kg of BW ^{0.75}					
N intake	2.46	2.20	2.30	0.082	0.201
Fecal N	0.773	0.636	0.657	0.060	0.322
Urine N	0.886	0.819	0.901	0.036	0.455
Milk total N	0.497 ^b	0.343 ^a	0.343 ^a	0.036	0.012
Milk protein N	0.405 ^b	0.317 ^a	0.317 ^a	0.012	0.023
Digestible N ²	1.68	1.56	1.65	0.069	0.583
N balance ³	0.798	0.741	0.745	0.065	0.929
Retained N ⁴	0.301 ^a	0.397 ^b	0.402 ^b	0.067	0.050
N utilization, %					
Digestible N/intake N	69.2	71.4	71.5	1.96	0.452
N balance/digestible N	46.8	46.7	43.1	2.47	0.792
Milk protein N/digestible N	25.1	20.6	19.8	1.77	0.239
Milk protein N/N balance	55.6 ^b	48.2 ^a	53.1 ^b	6.21	0.050
Milk protein N/milk total N	88.6	93.1	92.2	0.433	0.491
Milk protein N/intake N	16.9	14.5	14.0	1.06	0.289
Energy utilization, MJ/kg of BW ^{0.75}					
Energy intake	1.51 ^b	1.37 ^a	1.52 ^b	0.490	0.016
Fecal energy	0.488	0.448	0.449	0.031	0.502
Urine energy	0.056 ^b	0.043 ^a	0.062 ^b	0.003	0.043
Milk energy	0.258 ^b	0.218 ^a	0.219 ^a	0.017	0.049
Digestible energy ⁵	1.03	0.92	1.07	0.04	0.116
Methane energy ⁶	0.106	0.095	0.111	0.04	0.180
ME ⁷	0.863	0.781	0.899	0.035	0.173
Energy utilization, %					
Digestible energy/energy intake	68.3	67.5	70.3	1.61	0.418
Milk energy/digestible energy	25.1	24.0	21.0	1.75	0.136
Milk energy/ME	29.8	28.4	25.2	2.12	0.194
ME/energy intake	57.5	57.3	58.9	1.47	0.676
ME/digestible energy	84.3	84.9	83.7	0.312	0.052

^{a,b}Within a row, means without a common superscript letter differ ($P < 0.05$).

¹AC = 707 g of alfalfa hay and 916 g of concentrate; ACBI = 789 g of alfalfa hay, 497 g of concentrate, and 209 ± 32 g of feed block I; ACBII = 811 g of alfalfa hay, 498 g of concentrate, and 346 ± 56 g of feed block II (fresh matter basis).

²Digestible N = intake N – fecal N.

³N balance = digestible N – urine N.

⁴Retained N = N balance – milk total N.

⁵Digestible energy = energy intake – fecal energy.

⁶Methane energy = methane output calculated from Aguilera (2001) as 10.32% of digestible energy.

⁷ME = digestible energy – urine energy – methane energy.

Table 6. Mean values for creatinine, urinary excretion of purine derivatives, microbial N flow, and efficiency of microbial N synthesis in dairy goats fed the experimental diets (n = 18)

Item	Diet ¹			SEM	P-value
	AC	ACBI	ACBII		
Creatinine, $\mu\text{mol/kg}^{0.75}$	508	501	477	21.4	0.530
Purine derivatives in urine, $\mu\text{mol/kg}^{0.75}$					
Allantoin	512	512	515	18.9	0.995
Xanthine	45.2 ^b	38.3 ^{ab}	29.7 ^a	4.15	0.036
Hypoxanthine	56.7	40.9	55.1	5.63	0.553
Uric acid	38.8	29.4	39.1	3.58	0.667
Total	653	620	639	24.8	0.924
Microbial N flow, g/d					
SAB ²	27.6 ^b	17.3 ^a	23.4 ^b	1.26	0.045
LAB ²	20.9 ^b	13.5 ^a	15.3 ^a	0.96	0.043
EMNS, ³ g/kg of OMAFR					
SAB	49.1 ^b	38.8 ^a	44.4 ^{ab}	2.75	0.036
LAB	37.4 ^b	30.2 ^a	29.2 ^a	2.28	0.045

^{a,b}Within a row, means without a common superscript letter differ ($P < 0.05$).

¹AC = 707 g of alfalfa hay and 916 g of concentrate; ACBI = 789 g of alfalfa hay, 497 g of concentrate, and 209 $\pm$ 32 g of feed block I; ACBII = 811 g of alfalfa hay, 498 g of concentrate, and 346 $\pm$ 56 g of feed block II (fresh matter basis).

²SAB = solid associated bacteria, LAB = liquid associated bacteria.

³Efficiency of microbial N synthesis; OMAFR = OM apparently fermented in the rumen (65% of digestible OM intake; ARC, 1984).

Fava beans are local legume seeds that goats like (Sanz Sampelayo et al., 1999).

The disagreement in response pattern in DM and OM could be due to the different mineral contents in experimental diets. Our results do not agree with those reported by Ben Salem and Znaidi (2008), who noted that partial replacement of concentrate with FB de-

creased OM digestibility but increased CP digestibility of straw-based diets given to Barbarine lambs. The lower fat digestibility of diets including FB compared with diet AC is difficult to explain because the CTSOC is a pasty material readily available for digestion and absorption. Fat digestibility in ruminants depends to a great extent upon fat availability for both digestion and

Table 7. Effect of type of diet on milk composition and production (n = 18)

Item	Diet ¹			SEM	P-value
	AC	ACBI	ACBII		
Milk composition, g/kg					
Protein	31.8	33.8	31.1	1.20	0.657
Casein	25.3	26.7	23.7	1.12	0.581
Whey protein	6.60	7.12	7.48	0.327	0.294
Fat	45.9	49.7	42.7	2.24	0.547
Lactose	47.6	44.9	43.3	2.11	0.882
Total solid	131	139	127	3.12	0.144
Gross energy, MJ/kg	3.25	3.51	3.36	0.113	0.533
Milk yield, g/d					
Milk	1,255 ^b	973 ^a	1,029 ^a	81.4	0.016
Protein	38.8 ^b	31.3 ^a	31.6 ^a	2.68	0.017
Casein	30.8 ^b	24.7 ^a	24.0 ^a	2.86	0.032
Whey protein	8.01	6.61	7.56	0.739	0.245
Fat	54.5 ^b	46.7 ^{ab}	43.0 ^a	2.99	0.030
Lactose	61.7 ^b	45.0 ^a	44.7 ^a	4.86	0.049
Total solid	163 ^b	132 ^a	128 ^a	9.14	0.001
Gross energy, MJ/d	3.97	3.36	3.44	0.269	0.118

^{a,b}Within a row, means without a common superscript letter differ ($P < 0.05$).

¹AC = 707 g of alfalfa hay and 916 g of concentrate; ACBI = 789 g of alfalfa hay, 497 g of concentrate, and 209 $\pm$ 32 g of feed block I; ACBII = 811 g of alfalfa hay, 498 g of concentrate, and 346 $\pm$ 56 g of feed block II (fresh matter basis).

Table 8. Fatty acid composition (g/100 g of identified fatty acids) of milk fat for goats fed the experimental diets (n = 18)

Item	Diet ¹			SEM	P-value
	AC	ACBI	ACBII		
C4:0	3.22 ^b	3.24 ^b	2.13 ^a	0.17	0.002
C6:0	3.29 ^b	3.50 ^b	2.37 ^a	0.17	0.010
C8:0	3.51 ^b	3.47 ^b	2.87 ^a	0.10	0.003
C10:0	11.2 ^b	10.8 ^b	9.53 ^a	0.31	0.029
C12:0	5.18	5.01	4.53	0.28	0.328
C14:0	10.9	10.9	10.8	0.29	0.873
C14:1	0.207 ^a	0.366 ^b	0.512 ^b	0.043	0.041
C16:0	34.1	33.2	34.2	0.81	0.866
C16:1	0.071	0.135	0.218	0.055	0.710
C18:0	6.48	5.69	6.37	0.45	0.626
C18:1 (<i>trans</i> -11)	0.122 ^a	0.187 ^a	0.432 ^b	0.040	0.050
C18:1 (<i>cis</i> -9)	18.2	19.7	22.1	1.14	0.442
C18:2 (<i>cis</i> -9,12)	2.11	2.16	2.14	0.111	0.559
C18:2 (<i>trans</i> 10,12)	0.044 ^a	0.058 ^b	0.075 ^c	0.014	0.040
C18:2 (<i>cis</i> -9, <i>trans</i> -11)	0.436 ^a	0.522 ^b	0.590 ^b	0.040	0.020
C18:3 (<i>cis</i> -6, 9, 12)	0.475 ^a	0.671 ^b	0.676 ^b	0.042	0.033
C20:0	0.140	0.144	0.162	0.025	0.651
C20:4	0.278	0.299	0.197	0.036	0.441
CLA ²	0.470 ^a	0.580 ^b	0.665 ^b	0.038	0.012
Medium-chain fatty acids	37.5 ^b	37.2 ^b	32.8 ^a	0.913	0.043
Monounsaturated fatty acids	18.6	20.4	23.3	0.835	0.164
Polyunsaturated fatty acids	3.34	3.71	3.68	0.185	0.241
Saturated fatty acids	78.1 ^b	75.9 ^b	73.1 ^a	0.773	0.046
C18:1 (<i>trans</i> -11):CLA	0.260 ^a	0.322 ^{ab}	0.650 ^b	0.102	0.045
Atherogenicity index ³	3.78 ^b	3.39 ^{ab}	3.04 ^a	0.289	0.022

^{a-c}Within a row, means without a common superscript letter differ ($P < 0.05$).

¹AC = 707 g of alfalfa hay and 916 g of concentrate; ACBI = 789 g of alfalfa hay, 497 g of concentrate, and 209 ± 32 g of feed block I; ACBII = 811 g of alfalfa hay, 498 g of concentrate, and 346 ± 56 g of feed block II (fresh matter basis).

²Conjugated linoleic acid.

³Calculated as $C12:0 + 4 \times C14:0 + C16:0$ /unsaturated fatty acids (Ulbricht and Southgate, 1991).

absorption (Grummer, 1988). Higher fiber digestibility found with FB diets compared with diet AC could indicate higher energy availability, but that does not seem to be the case in this experiment as neither DE nor ME was higher with diets including FB. Either the microbial protein synthesis or the corresponding efficiency obtained with FB diets was not higher compared with the AC diet.

The N balance was similar for the 3 experimental diets. Our results are in line with those obtained by Ben Salem and Znaidi (2008) as neither concentrate proportion in the diet nor the type of FB affected the N balance. Milk N and milk protein N/N balance ratio were higher for diet AC than for ACBI and ACBII. As stated by Bequette et al. (1999), the amino acid profile of a protein should be different for body retention and milk production. Lysine and methionine are the most limiting amino acids for milk production (Schwab et al., 1992). The presence of soybean meal, with high CP and lysine content (De Blas et al., 1994), in the concentrate could explain the results obtained in the present work.

According to Aguilera and Prieto (1991) and Aguilera (2001), the energy losses for methane production were estimated as 10.32 kJ/100 kJ of digestible energy. The energy destined to milk production was higher with diet AC than with the FB diets. This is in accordance with the higher milk yield and fat proportion as well as higher protein and lactose obtained with diet AC compared with the FB diets.

In contrast to our results, Chiofalo et al. (2004) found that protein and casein percentages in milk were higher in the control group compared with ewes fed olive cake-containing diets.

Recently, Devillard et al. (2004) suggested that CLA and VA contents were 4- to 5-fold higher in rumen protozoal cells than in bacteria, suggesting that protozoa may represent a major pool of CLA and VA in the rumen. In the present work, there did not seem to be a relationship between CLA and VA in milk and ruminal protozoa numbers.

The most abundant individual FA in milk were palmitic, oleic, capric, myristic, stearic, and lauric acids. Our results disagree with those of Chiofalo et al.

(2004), who found higher levels of palmitic, stearic, and oleic acids in milk from animals fed diets including olive cake. In agreement with Chiofalo et al. (2004), milk from animals receiving FB showed higher levels of linolenic acid; α -linolenic acid was not detected in milk. In the present experiment, the proportion of oleic acid in milk from animals fed diets AC, ACBI, and ACBII was similar, whereas proportions of linolenic acid and CLA were higher in milk from animals receiving the FB diets compared with those consuming the AC diet. Chiafalo et al. (2004) suggested a lack of biohydrogenation from oleic to stearic acid by rumen microorganisms with diets including the by-product because of their high lignin and polyphenol contents. These phenols increase rumen transit speed and promote a partial inactivity of rumen-specific microorganisms involved in stearic synthesis (Camurati and Fedeli, 1982).

Biohydrogenation of linolenic (Griinari and Bauman, 1999), oleic, and linoleic (Mosley et al., 2002; Jenkins et al., 2008) acids by rumen microorganisms produces VA. Inclusion of CTSOC, rich in oleic and linoleic FA, in animal diets could increase VA production. However, VA did not increase in milk from animals fed diet ACBI compared with diet AC. The concentration of VA was highest in milk from goats receiving diet ACBII, although FB II included less CTSOC than FB I. Because higher microbial protein synthesis seems to be promoted by diet ACBII compared with ACBI, a more active biohydrogenation in the rumen of goats fed diet ACBII could be partly responsible for the different VA content in milk from goats fed diets ACBI and ACBII. Milk from animals fed FB diets was high in rumenic acid and total CLA probably because of the isomerization of linoleic acid present in diets but also because of the desaturation of VA in both the rumen and mammary gland (Chilliard et al., 2003). As indicated by Chilliard et al. (2006), for goat milk the level of *trans*-10, *cis*-12 CLA isomer in milk was very low. The VA/CLA ratio was 0.260, 0.322, and 0.650 in milk from animals fed diets AC, ACBI, and ACBII, respectively. A linear correlation between rumenic acid and VA in milk under a wide variety of diets in dairy goats (Chilliard et al., 2003) or in dairy cows (Griinari et al., 2000) has been reported. Results obtained in Murciano-Granadina dairy goats (Bouttaour et al., 2008) showed similar levels of CLA and VA in milk as those observed in Alpine dairy goats. The Δ^9 -desaturase indexes are generally lower in goat milk than in cow milk for medium-chain FA, but not for C18 FA, which could suggest a species dependence of Δ^9 -desaturase activity according to FA chain length (Chilliard et al., 2006). Because CLA is considered healthy for consumers (Pariza, 2004), the inclusion of CTSOC in goats feeding could be an option to improve the nutritional quality of milk.

Considering the FA groups, the highest intake corresponded to polyunsaturated FA, then to monounsaturated FA, and finally to saturated FA; the values for all the 3 groups were higher for diet AC, followed by ACBI, and finally ACBII. In milk fat, the most abundant groups of FA were, in decreasing order, saturated, medium-chain, monounsaturated, and polyunsaturated FA. Average values for medium-chain and saturated FA in milk from animals fed diets AC and ACBI were higher than those receiving diet ACBII. The medium-chain FA percentage was more than 30% of total FA, which is one of the most specific characteristic of goats' milk (Haenlein, 2001).

The fatty acids with 16 or fewer carbon atoms derive from *de novo* synthesis, whereas those with 18 or more carbon atoms come from the diet or from mobilization of body reserves (Sanz Sampelayo et al., 1998). Medium-chain FA levels in milk indicated that the *de novo* synthesis was lower with diet ACBII than with the other 2 experimental diets, which is supported by the higher VA and CLA contents in milk from animals fed diet ACBII compared with diet AC. Because the percentage of FA with 18 or more carbon atoms were high in concentrate and feeding blocks (87.7, 83.9, and 85.7%, respectively), it seems that body lipid mobilization did not occur in the present experiment. Although of controversial value (Chilliard et al., 2006), the atherogenicity index, calculated as indicated by Ulbricht and Southgate (1991), was 3.78, 3.39, and 3.04 for fat milk from animals fed diets AC, ACBI, and ACBII, respectively. The milk fat composition found in the present experiment is typical for normal goat milk. Otherwise, increases in VA (250%) and rumenic acid (40%), reductions (5%) in the saturated FA and medium-chain FA, and the lowest atherogenicity index in milk from animals fed the ACBII diet compared with the AC diet indicated that milk fat from animals fed the ACBII diet may be considered the one with the greatest healthy quality.

CONCLUSIONS

Feed blocks containing olive cake could be used when feeding dairy goats to partially replace concentrate without detrimental effects on nutrient (mainly N) utilization. Overall, FB improved quality of milk compared with a conventional diet. The decrease of milk yield with diet ACBII could be tolerated when considering the healthier quality of milk obtained with this diet compared with diets AC and ACBI, the lower cost of feeding diets including FB, and the environmental advantage of recycling by-products. More work on FB formulation is needed to make better use of alternative feed supplements in dairy goats.

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REFERENCES

- Aguilera, J. F. 2001. Aportaciones al conocimiento de la nutrición energética de pequeños rumiantes, con particular referencia al ganado caprino. *Arch. Zootec.* 50:565–596.
- Aguilera, J. F., and C. Prieto. 1991. Methane production in goats given diets based on Lucerne hay and barley. *Arch. Anim. Nutr.* 41:77–82.
- Aguilera, J. F., C. Prieto, and J. Fonollá. 1990. Protein and energy metabolism of lactating Granadina goats. *Br. J. Nutr.* 63:165–175.
- Al-Jassim, R. A. M., F. T. Awadeh, and A. Abodabos. 1997. Supplementary feeding value of urea-treated olive cake when fed to growing Awassi lambs. *Anim. Feed Sci. Technol.* 64:287–292.
- ARC. 1984. The Nutrient Requirement of Ruminant Livestock (No.1). Commonwealth Agriculture Bureaux, Slough, UK.
- AOAC. 2005. Official Methods of Analysis of the AOAC. 18th ed. AOAC. AOAC International, Gaithersburg, MD.
- Balcells, J., J. A. Guada, J. M. Peiró, and D. S. Parker. 1992. Simultaneous determination of allantoin and oxypurines in biological fluids by high-performance liquid chromatography. *J. Chromatogr. A* 575:153–157.
- Ben Salem, H., and A. Nefzaoui. 2003. Feed blocks as alternative supplements for sheep and goats. *Small Rumin. Res.* 49:275–288.
- Ben Salem, H., and I. Znaidi. 2008. Partial replacement of concentrate with tomato pulp and olive cake-based feed blocks as supplements for lambs fed wheat straw. *Anim. Feed Sci. Technol.* 147:206–222.
- Bequette, B. J., F. R. C. Backwell, C. E. Kyle, A. G. Calder, V. Buchan, L. A. Crompton, J. France, and J. C. MacRae. 1999. Vascular sources of phenylalanine, tyrosine, lysine, and methionine for casein synthesis in lactating goats. *J. Dairy Sci.* 82:362–377.
- Bouattour, M. A., R. Casals, E. Albanell, X. Such, and G. Caja. 2008. Feeding soybean oil to dairy goats increases conjugated linoleic acid in milk. *J. Dairy Sci.* 91:2399–2407.
- Camurati, F., and E. Fedeli. 1982. Attività antiossidante di estratti fenolici delle acque di vegetazione delle olive. *Riv. Ital. Sost. Grasse.* 59:623–626.
- Chalupa, W., and A. J. Kutches. 1968. Biohydrogenation of linoleic-1-14C acid by rumen protozoa. *J. Anim. Sci.* 27:1502–1508.
- Chilliard, Y., A. Ferlay, J. Rouel, and G. Lamberet. 2003. A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. *J. Dairy Sci.* 86:1751–1770.
- Chilliard, Y., J. B. Rouel, and C. Leroux. 2006. Goat's alpha-s1 casein genotype influences its milk fatty acid composition and delta-9 desaturation ratios. *Anim. Feed Sci. Technol.* 131:474–487.
- Chiofalo, B., L. Liotta, A. Zumbo, and V. Chiofalo. 2004. Administration of olive cake for ewe feeding: Effect on milk yield and composition. *Small Rumin. Res.* 55:169–176.
- De Blas, C., G. G. Mateos, and P. García Rebollar. 1994. Normas FEDNA para la formulación de piensos compuestos. Elanco Veterinaria S.A., Madrid, Spain.
- Dehority, B. A. 1984. Evaluation of subsampling and fixation procedures used for counting rumen protozoa. *Appl. Environ. Microbiol.* 48:182–185.
- Delgado, C., M. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois. 1999. Livestock to 2020: The next food revolution. IFPRI Brief 61. Int. Food Policy Res. Inst., Washington, DC.
- Devillard, E., F. M. McIntosh, R. J. Castet, J. Wallace, and C. J. Newbold. 2004. Conjugated linoleic acid composition of rumen bacterial and protozoal populations. *Reprod. Nutr. Dev.* 44(Suppl. 1):60.
- Devillard, E., F. M. McIntosh, C. J. Newbold, and R. J. Wallace. 2006. Rumen ciliate protozoa contain high concentrations of conjugated linoleic acid and vaccenic acid, yet do not hydrogenate linoleic acid or desaturate stearic acid. *Br. J. Nutr.* 96:697–704.
- FAO. 2008. Significant increase in world cereal production forecast for 2008, but prices remain high. <http://www.fao.org/newsroom/en/news/2008/1000783/index.html>
- Griinari, J. M., and D. E. Bauman. 1999. Biosynthesis of conjugated linoleic acid and its incorporation into meat and milk in ruminants. Pages 180–200 in *Advances in Conjugated Linoleic Acid Research*. Volume 1. M. P. Yurawecz, M. M. Mossoba, J. K. G. Kramer, M. W. Pariza, and G. J. Nelson, ed. AOCS Press, Champaign, IL.
- Griinari, J. M., B. A. Corl, S. H. Lacy, P. Y. Chouinard, K. V. V. Nurmela, and D. E. Bauman. 2000. Conjugated linoleic acid is synthesized endogenously in lactating dairy cows by delta (9)-desaturase. *J. Nutr.* 130:2285–2291.
- Grummer, R. R. 1988. Influence of prilled fat and calcium salts of palm oil fatty acids on ruminal fermentation and nutrient digestibility. *J. Dairy Sci.* 71:117–123.
- Haenlein, G. F. W. 2001. Past, present, and future perspectives of small ruminant dairy research. *J. Dairy Sci.* 84:2097–2115.
- Hermoso, M., J. González, M. Uceda, A. García-Ortiz, J. Morales, L. Frías, and A. Fernández. 1995. Elaboración de Aceites de Oliva de Calidad. Obtención por el Sistema de dos Fases, ed. Junta de Andalucía, Spain.
- Jenkins, T. C., R. J. Wallace, P. J. Moate, and E. E. Mosley. 2008. Recent advances in biohydrogenation of unsaturated fatty acids within the rumen microbial ecosystem. *J. Anim. Sci.* 86:397–412.
- Jouany, J. P. 1995. Effect of rumen protozoa on nitrogen utilization by ruminants. *J. Nutr.* 126:1335S–1346S.
- Michalet-Doreau, B., and M. Y. Ould-Bah. 1992. Influence of haymaking on in situ nitrogen degradability of forages in cows. *J. Dairy Sci.* 75:782–788.
- Molina Alcaide, E., and D. R. Yáñez-Ruiz. 2008. Potential use of olive by-products in ruminant feeding: A review. *Anim. Feed Sci. Technol.* 147:247–264.
- Morand-Fehr, P., P. Bas, G. Blanchart, R. Daccord, S. Giger-Reverdin, E. A. Gihad, M. Hadjipanayiotou, A. Mowlem, F. Remeuf, and D. Sauvart. 1991. Influence of feeding on goat milk composition and technological characteristics. Pages 209–224 in *Goat Nutrition*. P. Morand-Fehr, ed. Pudoc Wageningen, Wageningen, the Netherlands.
- Mosley, E. E., G. L. Powell, M. B. Riley, and T. C. Jenkins. 2002. Microbial biohydrogenation of oleic acid to *trans* isomers in vitro. *J. Lipid Res.* 43:290–296.
- Mota, M., J. Balcells, N. H. Ozdemir Baber, S. Bölüktepe, and A. Belenguer. 2008. Modelling purine derivative excretion in dairy goats: Endogenous excretion and the relationship between duodenal input and urinary output. *Animal* 2:44–51.
- Pariza, M. W. 2004. Perspective on the safety and effectiveness of conjugated linoleic acid. *Am. J. Clin. Nutr.* 79:1132–1136.
- Park, Y. W. 2006. Goat milk. Chemistry and Nutrition. Pages 34–58 in *Handbook of Milk of Non-Bovine Mammals*. Y. W. Park and G. F. W. Haenlein, ed. Blackwell Publishing, Oxford, UK.
- Pearson, D. M. 1976. Laboratory Techniques in Food Analysis. Butterworths, London, UK.
- Rancourt, M., N. Fois, M. P. Lavín, E. Tchakériand, and F. Vallerand. 2006. Mediterranean sheep and goat production: An uncertain future. *Small Rumin. Res.* 62:167–179.

- Recio, I., M. L. Pérez-Rodríguez, L. Amigo, and M. Ramos. 1997. Study of the polymorphism of caprine milk caseins by capillary electrophoresis. *J. Dairy Res.* 64:515–523.
- Sanz Ceballos, L., M. R. Sanz Sampelayo, F. Gil Extremera, and M. Rodríguez Osorio. 2009. Evaluation of the allergenicity of goat milk, cow milk, and their lactosera in a guinea pig model. *J. Dairy Sci.* 92:837–846.
- Sanz Sampelayo, M. R., L. Pérez, J. Boza, and L. Amigo. 1998. Forage of different physical forms in the diets of lactating Granadina goats: Nutrient digestibility and milk production and composition. *J. Dairy Sci.* 81:492–498.
- Sanz Sampelayo, M. R., L. Pérez, F. Gil Extremera, J. Boza, and J. J. Boza. 1999. Use of different dietary protein sources for lactating goats: Milk production and composition as functions of protein degradability and amino acid composition. *J. Dairy Sci.* 82:555–565.
- Schwab, C. G., C. K. Bozak, N. L. Whitehouse, and M. M. A. Mesbah. 1992. Amino acid limitation and flow to duodenum at four stages of lactation. 1. Sequence of lysine and methionine limitation. *J. Dairy Sci.* 75:3486–3502.
- Ulbricht, T. L., and D. A. Southgate. 1991. Coronary heart disease: Seven dietary factors. *Lancet* 338:985–992.
- Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74:3583–3597.
- Yáñez-Ruiz, D. R., N. D. Scollan, R. J. Merry, and C. J. Newbold. 2006. Contribution of rumen protozoa to duodenal flow of nitrogen, conjugated linoleic acid and vaccenic acid in steers fed silages differing in their water-soluble carbohydrate content. *Br. J. Nutr.* 96:861–869.