**J. Dairy Sci. 88:757–765**

# Influence of Extruded Soybeans With or Without Bicarbonate on Milk Performance and Fatty Acid Composition of Goat Milk

**P. Schmidely, P. Morand-Fehr, and D. Sauvant**
Unité Mixte de Recherches “Physiologie de la Nutrition et Alimentation”,
Département des Sciences Animales, Institut National Agronomique, Paris-Grignon, 75231 Paris, France

## ABSTRACT

The effects of extruded soybeans (ESB) included at 0, 10, or 20% of dry matter (DM) of the diet in combination with sodium bicarbonate (0 vs. 1% bicarbonate added to DM) on rumen fermentation characteristics, production parameters, and fatty acid (FA) profiles of milk fat were examined in 30 midlactation goats and 6 rumen-cannulated goats fed high-concentrate diets (30:70 forage-to-concentrate ratio) ad libitum in a 3 × 2 factorial design. Diets were fed as total mixed rations. The trial lasted 13 wk with the final 9 wk as the test period. Milk yield and composition were recorded each week throughout the trial. Individual samples of milk were taken in wk 4, 7, 10, 11, and 13 to determine FA profile of milk fat. Dry matter intake and intake of net energy for lactation were not affected by dietary treatments. Feeding ESB did not modify ruminal pH or volatile fatty acids concentration in the rumen fluid, but it increased the molar proportion of propionate. Feeding ESB increased fat-corrected milk, milk fat content, and fat yield compared with the control diets. There was no change in milk protein content when ESB were fed. Feeding ESB increased the proportions of oleic, linoleic, and linolenic acids in milk fat at the expense of most of the saturated FA. It also increased the n-6 to n-3 FA ratio of milk. The largest changes in milk yield and milk composition were generally obtained with ESB included at 20% of DM. The addition of sodium bicarbonate tended to increase ruminal pH, VFA concentrations in the rumen fluid, and the molar proportions of acetate. The addition of sodium bicarbonate increased milk fat content and fat yield, with no change in milk FA composition. It is concluded that during midlactation, the inclusion of ESB to 20% of DM prevented low milk fat content for goats fed high-concentrate diets, with no decrease in milk protein content. The addition of sodium bicarbonate may enhance the effects of ESB on milk fat content and fat yield.

(**Key words:** milk fatty acids, bicarbonate, extruded soybean, goat)

**Abbreviation key: ESB** = extruded soybeans, **FA** = fatty acids.

## INTRODUCTION

In Europe, the popularity of dairy products from goats increased during the last 20 yr because of their nutritional value and a more favorable perception than dairy products from cows. Most dairy products from goats are cheese, in which quality is influenced by milk fat and protein contents (Brown et al., 1995). However, farmers face problems of low milk fat content (Morand-Fehr et al., 2000), which is related to the feeding of high-concentrate diets (Calderon et al., 1984; Santini et al., 1992). With high-concentrate diets, the fatty acids (**FA**) profile of milk fat from goats is altered: the proportions of medium-chain saturated FA (especially capric and lauric acids), long-chain saturated FA, and *cis*-C18:1 are reduced (Calderon et al., 1984; Ledoux et al., 2002). Simultaneously, the proportions of *trans*-C18:1 and linoleic acid in milk fat increase, with conflicting results for linolenic acid (Calderon et al., 1984; Ledoux et al., 2002). Similar results are obtained with high-concentrate diets fed to dairy cows (reduction of milk fat content, increase in *trans*-C18:1 fatty acids in milk). These effects may be reduced by adding a buffer (Kennelly et al., 1999; Khorasani and Kennelly, 2001) that modifies the extent of biohydrogenation of dietary polyunsaturated FA in the rumen (Kalscheur et al., 1997). In dairy goats, the addition of sodium bicarbonate to the diet reduces the milk fat depression associated with high-concentrate diets (Hadjipanayiotou, 1982, 1988) but no effect on the milk FA profile is reported.

In dairy cows, milk fat content and FA profile of milk fat may be altered by the addition of lipids to the diet (Chilliard et al., 2000). When full-fat or extruded soybeans (**ESB**) are fed, the milk fat content and the proportions of lauric, myristic, and palmitic acids are reduced, whereas the proportions of linoleic and linolenic acids are increased (Dhiman et al., 1999; Abu-Gazalleh et al., 2002; Whitlock et al., 2002). In goats, data ob-

---

Received March 16, 2004.
Accepted October 12, 2004.

Corresponding author: P. Schmidely; e-mail: schmidel@inapg.inra.fr.

tained from adding oilseeds or oil from oilseeds are scarce (Daccord, 1987; Baldi et al., 1992; Gulati et al., 1997), and goats respond quite differently to lipid supplementation than do cows (Schmidely and Sauvant, 2001; Chilliard et al., 2003). Moreover, the effect of ESB inclusion in the diet on FA profile of milk fat has been poorly documented (Chilliard et al., 2003).

Consequently, this study investigated the effects of different levels of ESB in the diet (with or without sodium bicarbonate) on milk yield and composition, the proportions of FA in milk fat, and the rumen fermentation characteristics in midlactation goats. Parts of these results have been previously published (Schmidely et al., 2001).

## MATERIALS AND METHODS

### Goats and Diets

Thirty-six Alpine or Saanen multiparous goats (20 Alpine, 16 Saanen), 6 of which were fitted with rumen cannulas, were used for 13 wk from 90 ± 15 DIM. The first 4 wk were for adaptation to the experimental diets, and the final 9 wk were used as the test period. The goats were housed individually in 2- × 1-m shaded pens with wooden floors and they had free access to water and to a trace-mineralized salt block. They were machine-milked twice daily (0700 and 1600 h). Milk yield, milk fat content, and milk protein content were recorded on 2 consecutive days each week throughout the trial. Samples from 2 consecutive (a.m. and p.m.) milkings were taken in wk 4, 7, 10, 11, and 13 for the determination of FA profile of milk fat. Once weekly, the goats were weighed at 1400 h.

All diets were fed twice daily in 2 equal meals (0800 and 1700 h) to achieve ad libitum intake; orts always represented more than 5% of distributed feed. The amount of feed distributed and orts were recorded daily. During the first 2 wk of the trial, the goats were fed a control diet as TMR, consisting of 30% dehydrated alfalfa pellets (DM basis), 20% sugar beet pulp silage, and 50% concentrate (50:50 mixture of barley and soybean meal). For the next 2 wk, the goats were gradually introduced to 1 of 6 experimental diets by mixing the control and the experimental diet at 80:20 on d 1, at 60:40 on d 3, at 40:60 on d 6, at 20:80 on d 8, and at 0:100 on d 10.

The 6 experimental diets fed as TMR contained dehydrated alfalfa pellets, sugar beet pulp silage, and an experimental concentrate (Table 1) in similar proportions as in the diet fed in the first 2 wk. The concentrates were formulated by a factorial combination of 2 levels of sodium bicarbonate (0 vs. 1% bicarbonate added in the DM of the TMR) and 3 levels of inclusion of ESB (0 vs. 10 vs. 20% of DM in the TMR) in substitution of soybean meal and part of soybean hulls. The substitution was calculated to maintain approximately the same protein content in the 6 diets. Full-fat soybeans were purchased locally and they were dry-extruded in an experimental extruder at the CETIOM (Center d'Etudes Technique pour les Oléagineux Métropolitains, CREOL, Pessac, France). The flux of extrusion was 225 kg/h with a maximal measured temperature of 100°C.

The 30 uncannulated and the 6 cannulated goats were randomly assigned to the 6 experimental diets. At the end of the trial (wk 13), rumen fluid samples were collected before and 1, 2, and 3 h after morning feeding. The pH of the ruminal fluid was determined using a glass electrode pH meter after straining through cheesecloth. An aliquot of 1 mL of ruminal fluid was mixed with 1 mL of distilled water and 0.1 mL of $HgCl_2$ (5%, wt/vol) was thoroughly shaken, and frozen at –20°C for later analysis of VFA. A second 1-mL aliquot was mixed with 0.1 mL of $HgCl_2$ and 5 mL of trichloracetic acid, (2.5% wt/vol) shaken, and frozen to -20°C for subsequent analysis of ammonia.

### Sampling Procedures and Chemical Analysis

Representative samples of diets and orts were collected 4, 8, and 12 wk after the start of the trial and frozen for analysis. Samples (100 g) of diets and orts were used to determine DM and ash content (only for diets) in duplicate. Samples of diets (1 g) were used for the determination of N and ether extract contents in duplicate, and for NDF and ADF content in triplicate. The DM content of diets and orts was measured by 72-h freeze-drying to a constant weight. The OM content of diets was obtained after ashing at 550°C for 12 h. The NDF and ADF contents were determined according to the method of Van Soest et al. (1991). Total N of diets was determined by the microKjeldahl technique. Ether extract of diets was determined using petroleum ether (Soxtec, 1043 Extraction Unit, Tecator, France). For each diet, the FA composition was calculated using published values of the FA profile of each ingredient (INRA-AFZ, 2002). The daily intake of each FA was then calculated by goat, by multiplying daily DMI by the proportion of each FA in the DM.

The ruminal ammonia concentration was determined as described by Wheatherburn (1967) using an Autoanalyzer (Technicon, France). The ruminal VFA concentrations were analyzed by gas chromatography (Variant 3400, Les Ulis, France), with a 2-m glass column packed with SP 1200 (10%) + 1% $H_3PO_4$ on Chromosorb W AW (80/100 mesh) (Supelco, Bellefonte, PA) as described by Kristensen et al. (2000).

Milk fat and protein were determined by near infrared analysis (Milkoscan; Foss Electric, Hillerød, Den-

**Table 1.** Composition and chemical analysis of the experimental diets.

| | Diets[1] | | | | | |
|---|---|---|---|---|---|---|
| | No sodium bicarbonate | | | With sodium bicarbonate | | |
| | ESB0 | ESB10 | ESB20 | ESB0 | ESB10 | ESB20 |
| Ingredient composition, % of DM | | | | | | |
| Dehydrated alfalfa pellets | 31 | 31 | 31 | 30 | 30 | 30 |
| Sugar beet pulp silage | 20 | 20 | 20 | 20 | 20 | 20 |
| Barley | 10 | 10 | 10 | 10 | 10 | 10 |
| Soybean hulls | 26 | 23 | 18 | 26 | 23 | 18 |
| Soybean meal | 12 | 5 | 0 | 12 | 5 | 0 |
| Extruded soybeans | 0 | 10 | 20 | 0 | 10 | 20 |
| Vitamin and mineral mixture[2] | 1 | 1 | 1 | 1 | 1 | 1 |
| Sodium bicarbonate | 0 | 0 | 0 | 1 | 1 | 1 |
| Chemical analysis, g/kg of DM | | | | | | |
| Ash | 7.5 | 7.4 | 7.3 | 7.7 | 7.6 | 7.5 |
| CP | 18.4 | 18.4 | 19.1 | 18.2 | 18.2 | 18.9 |
| Ether extract | 1.38 | 3.28 | 5.19 | 1.37 | 3.27 | 5.18 |
| NDF | 42.5 | 41.5 | 39.9 | 42.1 | 41.1 | 39.5 |
| ADF | 26.1 | 25.0 | 23.1 | 25.7 | 24.6 | 22.9 |
| $NE_L$, MJ/kg of DM | 6.60 | 6.68 | 6.79 | 6.55 | 6.64 | 6.74 |
| PDIA,[3] g/kg of DM | 55 | 60 | 67 | 55 | 59 | 67 |
| PDIN,[3] g/kg of DM | 122 | 123 | 129 | 121 | 122 | 128 |
| PDIE,[3] g/kg of DM | 112 | 117 | 121 | 111 | 116 | 120 |

[1] ESB0, ESB10, and ESB20: 0, 10, and 20% of extruded soybeans in the diet (% of DM).

[2] Mineral contained 30% dicalcium phosphate; 20% sodium bicarbonate; 20% trace-mineralized salt; 20% limestone; 4% $CaSO_4$; 4% $MgO_3$; 2% urea; 650,000 IU/kg of vitamin A; 350,000 IU/kg of vitamin D; and 4000 IU/kg of vitamin E.

[3] PDIA, PDIN, and PDIE = Digestible CP in the intestine from dietary origin, from microbial protein synthesis when availability of fermentable N in the rumen is limiting, and from microbial protein synthesis when availability of energy in the rumen is limiting, respectively (INRA, 1989).

mark) in the laboratory of the Contrôle Laitier (Syndicat Interdepartemental de l'Elevage, Le Mee, France). Milk fat was extracted with chloroform:methanol (2:1, vol/vol) and the fat extract was purified by saponification with 15 mL of 2 *N* potassium hydroxide solution in 95% ethanol (vol/vol). Fatty acids were released with 15 mL of 6 *N* HCl, and then extracted 3× with 30 mL of hexane. The fatty acids were methylated at 70°C with a methanolic boron trifluoride solution (14% wt/vol). The fatty acid methyl esters were separated by GLC (Variant 3400, Les Ulis, France) fitted with a flame ionization detector. Samples were directly injected through the splitless injection port onto a fused silica capillary column DB-Wax (60-mL × 0.25-mm i.d. × 0.25-μm e). Helium was used as a carrier gas (0.95 mL/min). The temperature of the injector was 230°C, and that of the detector was 250°C. The initial oven temperature was 60°C (for 1 min), increased at 10°C/min to 120°C (held for 20 min), increased at 3°C/min to 190°C (held for 50 min), and increased at 10°C/min to 210°C (held for 20 min). The peak of each fatty acid was identified by comparing the retention time of pure methyl ester standards (Interchim, Montluon, France). The percentage of each fatty acid was calculated as the ratio of the area under the curve of the peak to the total area under the curve of the reported peaks.

## Statistical Analyses

Data (except for the rumen data) were analyzed using the MIXED procedure of SAS (SAS Institute, 2000) for repeated measurements with the model:

$$Y_{ijkl} = \mu + ESB_i + B_j + ESB_i \times B_j + G_k + T_l + ESB_i \times T_l + B_j \times T_l + ESB_i \times B_j \times T_l + C + E_{ijkl}$$

where $\mu$ = overall mean, $ESB_i$ = fixed effect of ESB (2 df), $B_j$ = fixed effect of sodium bicarbonate (1 df), $ESB_i \times B_j$ = fixed effect of interaction between $ESB_i$ and $B_j$ (2 df), $G_k$ = random effect of the kth goat, $T_l$ = fixed effect of the lth measurement (3 df for FA composition, 8 df for the other data). The terms $ESB_i \times T_l$, $B_j \times T_l$, $ESB_i \times B_j \times T_l$ were the interactions between the fixed effect of the lth measurement and the experimental factors. The term C was an appropriate covariate (e.g., milk yield, milk composition, or BW) measured during the last 2 wk of the adaptation period, and $E_{ijk}$ was the residual error. First order autoregressive [AR(1)] was used as the covariance structure.

**Table 2.** Influence of sodium bicarbonate (B) and extruded soybeans (ESB) on milk yield and composition, DMI, and $NE_L$ balance.[1]

| | Diets[2] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No sodium bicarbonate | | | With sodium bicarbonate | | | | $P <$ | | |
| Item | ESB0 | ESB10 | ESB20 | ESB0 | ESB10 | ESB20 | SEM | ESB | B | ESB × B |
| Yield, kg/d | | | | | | | | | | |
| Milk | 3.30$^{a}$ | 3.41$^{a}$ | 3.77$^{b}$ | 3.44$^{ab}$ | 3.46$^{ab}$ | 3.63$^{ab}$ | 0.127 | † | NS | NS |
| FCM | 3.35$^{a}$ | 3.72$^{b}$ | 3.94$^{bc}$ | 3.75$^{b}$ | 3.71$^{b}$ | 4.10$^{b}$ | 0.123 | * | NS | NS |
| Fat | 0.11$^{a}$ | 0.13$^{b}$ | 0.14$^{b}$ | 0.13$^{b}$ | 0.13$^{b}$ | 0.15$^{c}$ | 0.005 | ** | ** | NS |
| Protein | 0.10 | 0.11 | 0.12 | 0.11 | 0.11 | 0.12 | 0.003 | NS | NS | NS |
| Composition, g/kg milk | | | | | | | | | | |
| Fat | 33.4$^{a}$ | 38.5$^{b}$ | 36.9$^{ab}$ | 37.4$^{b}$ | 38.4$^{b}$ | 43.1$^{c}$ | 0.95 | ** | ** | † |
| Protein | 31.8 | 32.0 | 31.7 | 32.2 | 31.0 | 31.8 | 0.47 | NS | NS | NS |
| Fat:protein ratio | 1.05$^{a}$ | 1.20$^{b}$ | 1.16$^{ab}$ | 1.16$^{ab}$ | 1.24$^{b}$ | 1.36$^{c}$ | 0.02 | ** | *** | † |
| BW, kg | 65.6 | 64.7 | 68.3 | 65.5 | 64.2 | 65.7 | 1.57 | NS | NS | NS |
| DMI, kg/d | 2.67 | 2.51 | 2.74 | 2.78 | 2.58 | 2.58 | 0.05 | NS | NS | NS |
| $NE_L$ intake, Mcal/d | 4.25 | 4.01 | 4.40 | 4.42 | 4.12 | 4.14 | 0.087 | NS | NS | NS |
| $NE_L$ balance, Mcal/d | 0.51$^{a}$ | 0.03$^{b}$ | 0.23$^{a}$ | 0.41$^{a}$ | 0.17$^{ab}$ | −0.08$^{b}$ | 0.08 | ** | NS | NS |

[a,b,c]Means with different superscripts differ significantly ($P < 0.05$).

[1]Values are least squares means. NS = Nonsignificant; †$P < 0.10$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

[2]ESB0, ESB10, and ESB20: 0, 10, and 20% of extruded soybeans in the diet (% of DM).

Data obtained during the 4 h of rumen sampling were averaged by goat, and were analyzed using the GLM procedure of SAS (SAS Institute, 2000) with the following model:

$$Y_{ijk} = \mu + ESB_i + B_j + E_{ijk}$$

where $\mu$ = overall mean, $ESB_i$ = fixed effect of ESB (2 df), $B_j$ = fixed effect of sodium bicarbonate (1 df), and $E_{ijk}$ was the residual error (2 df). No interaction between $ESB_i$ and $B_j$ could be tested because there were only 6 cannulated goats. Significance was declared at $P < 0.05$, unless otherwise stated.

## RESULTS

### Chemical Composition of Diets

The chemical composition of the diets is presented in Table 1. The diets were isonitrogenous (18.5 ± 0.38% CP in DM); all diets were markedly above requirements for digestible CP in the intestine (INRA, 1989) and CP requirements of NRC (1981) for dairy goats. The diets provided a calculated $NE_L$ value (INRA, 1989) that increased slowly in parallel with the inclusion of ESB. When compared with diet without ESB, the ESB diets had higher ether extract content (1.37 ± 0.7, 3.28 ± 1.0, and 5.19 ± 1.19%, respectively, in DM for the diets containing 0, 10, and 20% ESB, independently of buffer addition) and similar ADF content (average content 24.6 ± 1.4% in DM). These findings were expected because of the substitution of soybean hulls and soybean meal by ESB. The mineral mixture fed in all groups had 20% sodium bicarbonate and it was fed to 1% of TMR. Consequently, the daily intake of sodium bicarbonate for the goats fed the diets with no added buffer was 5.0 to 5.5 g, and it was 31.0 to 34 g for the goats fed the diets with added buffer.

### DMI, Milk Yield, and Composition

Dry matter intake, BW, and $NE_L$ intake were not affected by the dietary treatments (Table 2), or by the interaction between the dietary treatments and time (data not shown). The interaction between ESB and bicarbonate was not significant for milk yield, FCM, yields of fat and protein, milk protein percentage, and $NE_L$ balance (Table 2). Calculated daily intake for each FA increased with the proportion of ESB in the diet (Table 3).

The ESB diet tended to increase milk yield ($P < 0.10$), and increased FCM, fat yield, and milk fat percentage (Table 2); the goats fed the 20% ESB diets had the highest values for milk yield, FCM, and fat yield. As the ESB diet had no effect on the yield of protein or on milk protein percentage, the milk fat to milk protein ratio was increased for the goats fed the ESB diets compared with those fed the control diets. The differences in milk yield, FCM, fat yield, and milk fat to milk protein ratio between the goats fed the ESB diets and those fed the control diets increased all along the trial (time × ESB effect: $P < 0.05$ for all these variables; data not shown). Because of the increase in FCM without any change in $NE_L$ intake, the goats fed the ESB diets

**Table 3.** Influence of sodium bicarbonate (B) and extruded soybeans (ESB) on calculated intake of fatty acids.[1]

| | Diets[2] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No sodium bicarbonate | | | With sodium bicarbonate | | | | $P <$ | | |
| Item | ESB0 | ESB10 | ESB20 | ESB0 | ESB10 | ESB20 | SEM | ESB | B | ESB × B |
| | (g/100 g of fat) | | | | | | | | | |
| C14:0 | $1.6^{a}$ | $1.4^{b}$ | $1.1^{c}$ | $1.7^{a}$ | $1.6^{ab}$ | $1.0^{c}$ | 0.05 | *** | NS | NS |
| C16:0 | $3.2^{a}$ | $7.2^{b}$ | $13.0^{c}$ | $3.4^{a}$ | $7.9^{b}$ | $12.4^{c}$ | 0.68 | *** | NS | NS |
| *Cis*-9 C16:1 | $0.1^{a}$ | $0.1^{b}$ | $0.2^{c}$ | $0.1^{a}$ | $0.1^{b}$ | $0.2^{c}$ | 0.01 | *** | NS | NS |
| C18:0 | $0.8^{a}$ | $2.4^{b}$ | $4.6^{c}$ | $0.9^{a}$ | $2.6^{b}$ | $4.4^{c}$ | 0.26 | *** | NS | NS |
| *Cis*-9 C18:1 | $5.1^{a}$ | $13.7^{b}$ | $25.7^{c}$ | $5.4^{a}$ | $15.0^{b}$ | $24.5^{c}$ | 1.42 | *** | NS | NS |
| *Cis*-(9,12) C18:2 | $13.6^{a}$ | $34.5^{b}$ | $64.0^{c}$ | $14.6^{a}$ | $37.8^{b}$ | $60.9^{c}$ | 3.47 | *** | NS | NS |
| *Cis*-(9,12,15) C18:3 | $1.3^{a}$ | $4.8^{b}$ | $8.1^{c}$ | $1.4^{a}$ | $5.3^{b}$ | $7.7^{c}$ | 0.47 | *** | NS | NS |

[a,b,c]Means with different superscripts differ significantly ($P < 0.05$).

[1]Values are least squares means. NS = Nonsignificant; ***$P < 0.001$.

[2]ESB0, ESB10, and ESB20: 0, 10, and 20% of extruded soybeans in the diet (% of DM).

had significantly lower $NE_L$ balances than those fed the controls diets.

Sodium bicarbonate increased fat yield, milk fat percentage, and milk fat to milk protein ratio (Table 2). The interaction between ESB and sodium bicarbonate tended to be significant ($P = 0.07$) for milk fat percentage and milk fat to milk protein ratio, as the goats fed the 20% ESB diet in combination with sodium bicarbonate had the highest values for these parameters.

### Ruminal Fermentation

Ruminal fermentation characteristics are presented in Table 4. Rumen pH before feeding was not affected by the dietary treatments (6.50 ± 0.06, data not shown). Feeding ESB had no effect on average rumen pH, rumen $NH_3$-N concentrations, and total rumen VFA concentrations. Feeding ESB increased the molar proportions of propionate and decreased the acetate to propionate ratio. Sodium bicarbonate tended to (weakly) increase ($P < 0.10$) the average rumen pH (+ 0.05 unit), the total rumen VFA concentrations ($P < 0.10$), and the molar proportions of acetate ($P < 0.05$).

### Fatty Acid Profile of Milk Fat

When compared with diets without ESB, feeding ESB sharply decreased the proportion of total saturated FA (Table 5), with a relative decrease between 20 and 40% for the straight saturated FA with 10 to 17 carbon units and for all FA presenting an iso- or an anteiso- structure. The maximal decrease in the proportions of these

**Table 4.** Influence of sodium bicarbonate (B) and extruded soybeans (ESB) on ruminal fluid fermentation characteristics.[1]

| | Diets[2] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No sodium bicarbonate | | | With sodium bicarbonate | | | | $P <$ | |
| Item | ESB0 | ESB10 | ESB20 | ESB0 | ESB10 | ESB20 | SEM | ESB | B |
| pH | 6.34 | 6.12 | 6.18 | 6.37 | 6.20 | 6.24 | 0.04 | NS | † |
| Ammonia-N, m*M* | 9.1 | 9.6 | 9.6 | 8.5 | 8.8 | 8.8 | 2.3 | NS | † |
| Total VFA, m*M* | 53.7 | 56.8 | 53.8 | 55.6 | 63.8 | 61.1 | 1.89 | NS | † |
| VFA, mol/100 mol | | | | | | | | | |
| Acetate (A) | $65.1^{a}$ | $65.8^{a}$ | $63.9^{ab}$ | $67.1^{b}$ | $67.2^{b}$ | $65.5^{a}$ | 0.44 | NS | * |
| Propionate (P) | $16.5^{a}$ | $17.9^{ab}$ | $18.8^{b}$ | $16.3^{a}$ | $17.1^{ab}$ | $18.1^{b}$ | 0.28 | * | NS |
| Butyrate | 15.0 | 13.3 | 14.5 | 13.4 | 13.3 | 13.6 | 0.25 | NS | NS |
| Isobutyrate | 1.1 | 0.9 | 0.9 | 1.0 | 0.9 | 1.0 | 0.05 | NS | NS |
| Valerate | 1.1 | 1.1 | 1.2 | 1.1 | 0.8 | 1.0 | 0.07 | NS | NS |
| Isovalerate | 1.2 | 1.0 | 0.8 | 1.1 | 0.7 | 0.8 | 0.06 | NS | NS |
| A:P ratio | $3.99^{a}$ | $3.77^{ab}$ | $3.42^{b}$ | $4.04^{a}$ | $3.97^{ab}$ | $3.68^{b}$ | 0.08 | * | NS |

[a,b]Means with different superscripts differ significantly ($P < 0.05$).

[1]Values are least squares means. NS = Nonsignificant; †$P < 0.10$; *$P < 0.05$.

[2]ESB0, ESB10, and ESB20: 0, 10, and 20% of extruded soybeans in the diet (% of DM).

**Table 5.** Influence of sodium bicarbonate (B) and extruded soybeans (ESB) on fatty acid composition of milk fat.[1]

| | Diets[2] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No sodium bicarbonate | | | With sodium bicarbonate | | | | $P <$ | | |
| Item | ESB0 | ESB10 | ESB20 | ESB0 | ESB10 | ESB20 | SEM | ESB | B | ESB × B |
| | (g/100 g of fat) | | | | | | | | | |
| C10:0 | $10.53^{a}$ | $9.95^{a}$ | $8.50^{b}$ | $10.80^{a}$ | $8.60^{b}$ | $8.74^{b}$ | 0.320 | *** | NS | NS |
| C12:0 | $5.45^{a}$ | $4.40^{b}$ | $3.90^{b}$ | $5.54^{a}$ | $3.00^{c}$ | $3.47^{b}$ | 0.269 | *** | NS | NS |
| C14:0 | $12.91^{a}$ | $11.85^{ab}$ | $10.66^{b}$ | $12.88^{a}$ | $11.91^{ab}$ | $9.84^{b}$ | 0.370 | *** | NS | NS |
| C15:0 | $1.37^{a}$ | $1.10^{b}$ | $1.01^{b}$ | $1.40^{a}$ | $1.01^{b}$ | $0.96^{b}$ | 0.051 | *** | NS | NS |
| C16:0 | $38.61^{a}$ | $29.30^{c}$ | $28.19^{c}$ | $39.58^{a}$ | $35.00^{b}$ | $27.84^{c}$ | 1.469 | *** | NS | NS |
| C17:0 | $0.89^{a}$ | $0.82^{ab}$ | $0.64^{b}$ | $0.93^{a}$ | $0.73^{ab}$ | $0.67^{b}$ | 0.030 | *** | NS | NS |
| C18:0 | $6.70^{a}$ | $11.71^{b}$ | $13.9^{b}$ | $6.09^{a}$ | $12.70^{b}$ | $16.06^{c}$ | 1.063 | *** | NS | * |
| C20:0 | $0.17^{a}$ | $0.23^{ab}$ | $0.25^{b}$ | $0.18^{a}$ | $0.26^{b}$ | $0.26^{b}$ | 0.015 | *** | NS | NS |
| iso-C14:0 | $0.14^{a}$ | $0.13^{a}$ | $0.10^{b}$ | $0.15^{a}$ | $0.13^{a}$ | $0.11^{b}$ | 0.007 | *** | NS | NS |
| iso-C16:0 | $0.40^{a}$ | $0.37^{a}$ | $0.30^{b}$ | $0.38^{a}$ | $0.35^{a}$ | $0.26^{b}$ | 0.018 | *** | NS | NS |
| iso-C18:0 | $0.10^{a}$ | $0.07^{b}$ | $0.06^{b}$ | $0.10^{a}$ | $0.07^{b}$ | $0.06^{b}$ | 0.005 | *** | NS | NS |
| anteiso-C15:0 | $0.55^{a}$ | $0.43^{b}$ | $0.40^{b}$ | $0.55^{a}$ | $0.40^{b}$ | $0.37^{b}$ | 0.026 | *** | NS | NS |
| anteiso-C17:0 | $0.73^{a}$ | $0.62^{b}$ | $0.52^{b}$ | $0.75^{a}$ | $0.51^{b}$ | $0.52^{b}$ | 0.029 | *** | NS | NS |
| *Cis*-9 C16:1 | $0.71^{a}$ | $0.53^{b}$ | $0.57^{b}$ | $0.68^{a}$ | $0.53^{b}$ | $0.52^{b}$ | 0.020 | *** | NS | NS |
| *Cis*-9 C18:1 | $12.37^{a}$ | $16.48^{b}$ | $17.66^{b}$ | $12.18^{a}$ | $14.60^{ab}$ | $17.93^{b}$ | 0.687 | *** | NS | NS |
| *Cis*-(9,12) C18:2 | $2.63^{a}$ | $3.81^{b}$ | $4.31^{b}$ | $2.58^{a}$ | $2.77^{a}$ | $4.62^{b}$ | 0.238 | *** | NS | † |
| *Cis*-(9,12,15) C18:3 | $0.48^{a}$ | $0.52^{b}$ | $0.52^{b}$ | $0.48^{a}$ | $0.48^{a}$ | $0.58^{c}$ | 0.015 | *** | † | † |
| C20:4, n-6 | 0.14 | 0.14 | 0.12 | 0.13 | 0.10 | 0.11 | 0.050 | NS | NS | NS |
| Others[3] | $5.12^{a}$ | $7.54^{b}$ | $8.39^{bc}$ | $4.62^{a}$ | $6.85^{b}$ | $7.08^{b}$ | 0.347 | *** | NS | NS |
| Saturated (S) | $78.55^{a}$ | $70.98^{c}$ | $68.43^{c}$ | $79.33^{a}$ | $74.67^{b}$ | $69.16^{c}$ | 1.295 | *** | NS | NS |
| Monounsaturated (M) | $13.08^{a}$ | $17.01^{b}$ | $18.23^{b}$ | $12.86^{a}$ | $15.13^{ab}$ | $18.45^{b}$ | 0.713 | *** | NS | NS |
| Polyunsaturated (P) | $3.25^{a}$ | $4.47^{b}$ | $4.95^{b}$ | $3.19^{a}$ | $3.35^{a}$ | $5.31^{c}$ | 0.242 | *** | NS | NS |
| S:(M + P) | $4.81^{a}$ | $3.30^{c}$ | $2.95^{c}$ | $4.94^{a}$ | $4.04^{b}$ | $2.91^{c}$ | 0.248 | *** | NS | NS |
| n-6:n-3 ratio[4] | $5.77^{a}$ | $7.60^{b}$ | $8.52^{c}$ | $5.65^{a}$ | $5.98^{a}$ | $8.16^{bc}$ | 0.318 | *** | NS | NS |

[a,b,c] Means with different superscripts differ significantly ($P < 0.05$).

[1] Values are least squares means. NS = Nonsignificant; †$P < 0.10$; *$P < 0.05$, ***$P < 0.001$.

[2] ESB0, ESB10, and ESB20: 0, 10, and 20% of extruded soybeans in the diet (% of DM).

[3] Unidentified peaks.

[4] n-6:n-3 ratio = (linoleic acid + arachidonic acid):linolenic acid.

FA was obtained for the goats fed the 20% ESB diets. Feeding ESB increased the proportions of long-chain saturated FA with 18 (stearic acid) or 20 (arachidic acid) carbon units (Table 5); the higher values for stearic acid were obtained for the goats fed the 20% ESB diets. Feeding ESB also increased the proportions of oleic acid (*cis*-9 C18:1), linoleic acid (*cis*-9, *cis*-12 C18:2), and linolenic acid (*cis*-9, *cis*-12, *cis*-15 C18:3); the relative increase for the goats fed the 20% ESB diets were higher for linoleic acid (+70%) than for oleic acid (+45%) and for linolenic acid (+12%). Feeding ESB increased linearly the proportions of unidentified FA. Feeding ESB decreased the ratio of saturated to unsaturated FA (Table 5), whereas it increased the ratio of n-6 to n-3 FA [(linoleic acid + arachidonic acid)/linolenic acid].

The addition of sodium bicarbonate tended to increase the proportion of linolenic acid ($P < 0.10$; Table 5). The interaction between ESB and bicarbonate tended to be significant ($P < 0.10$) for linoleic acid and for linolenic acid. When compared with the diet without ESB, the proportion of linoleic acid and linolenic acid were not affected by the combination of 10% ESB plus sodium bicarbonate, whereas feeding 10% ESB without sodium bicarbonate increased the proportion of these FA in milk fat. Sodium bicarbonate did not modify the saturated to unsaturated FA ratio, nor the n-6 to n-3 FA ratio.

## DISCUSSION

High-concentrate diets are known to produce a low fat content in milk of dairy goats (Calderon et al., 1984; Santini et al., 1992). In a review on dairy goats, Schmidely and Sauvant (2001) related milk fat content and percentage of concentrate in TMR by the relationship:

$$\text{milk fat content} = 44.6 - 0.13 \times \text{concentrate percentage (\% DM)},\ r = 0.98,\ 42 \text{ groups of goats.}$$

The use of this relationship in the present trial (70% concentrate) predicted a milk fat content of 35.6 g/kg of milk for the diet without added sodium bicarbonate and no ESB, which is close to the experimental value of 33.4 g/kg of milk. Consequently, it can be considered that the control diet induced a low milk fat content.

### Feeding Extruded Soybeans

Feeding ESB in various proportions (10 to 20% of DM) was reported to have either no effect on DMI in cows (Abu-Ghazaleh et al., 2002; Whitlock et al., 2002) or goats (Daccord, 1987), or a positive effect in cows (Dhiman et al., 1999). The changes in DMI with feeding full-fat oilseeds have been related to the initial concentration of lipids in the diet and to the quantity of added fat (Allen, 2000), without changes in DMI when added lipids represented 2 to 4% of diet DM. As $NE_L$ values of diets with 10 and 20% ESB were only 1.01 and 1.03 higher than that of the control diets, the differences in $NE_L$ intake were not significant in our trial. Consequently, the increase in FCM for the goats fed the ESB diets compared with those fed the control diets could not be attributed to higher $NE_L$ intake. Feeding the 20% ESB diets tended to increase raw milk yield by 10% and increased FCM by 13% over the control diets, which is in agreement with most of the data from cows (Dhiman et al., 1999; Abu-Ghazaleh et al., 2002; Whitlock et al., 2002). However, this finding is in contrast to data reported in early lactation goats fed 20% ESB in substitution of soybean meal (Daccord, 1987). It is possible that the response of raw milk yield to lipid supplementation is different during early and midlactation in dairy goats (Chilliard et al., 2003). A second explanation could be that the increase in FCM may result from an increase in protein delivery to the small intestine with the ESB, as adequate delivery of protein to the small intestine has been shown to be limiting for optimal milk production (DePeters and Cant, 1992). In our trial, the ESB diets had digestible CP in the intestine from dietary origin values (corresponding with RUP in the NRC system) that were 7 and 17% higher than the control diets, which corresponds approximately with the increase in FCM. Another possibility could be that the modifications in ruminal fermentation characteristics with ESB favored an increase in the flux of glucose to the mammary gland for milk production. Indeed, we observed an increase in the proportion of propionate in the ruminal fluid of goats fed the ESB diets (between 6 and 13%) compared with goats fed the control diets. No other effects of ESB on ruminal fermentation characteristics (pH, VFA concentration, $NH_3$) were observed.

When compared with the control diets, feeding the ESB diets increased fat yields (average of 15%, or 20 g/d) more dramatically than raw milk yield; consequently, milk fat content was significantly higher in the goats fed the ESB diets, particularly when bicarbonate was added. This increase in milk fat content was of the same magnitude as that reported by Daccord (1987) with dairy goats. However, these results are in contrast to most of the data reported in cows, where feeding ESB did not affect fat yield and decreased milk fat content (Abu-Ghazaleh et al., 2002; Whitlock et al., 2002). Such differences between species (dairy goat vs. dairy cow) for milk fat response to dietary fat supplementation has been already reported (Schmidely and Sauvant, 2001) and could be related to differences in the metabolism of fatty acids in the rumen or in the mammary gland. Indeed, cows fed high-concentrate diets rich in polyunsaturated FA had higher *trans*-10 C18:1 or *trans*-10,*cis*-12 C18:2 (an isomer of conjugated linoleic acid), which induced low milk fat content (Piperova et al., 2000), whereas no change in milk fat content was observed in goats fed vegetable oil despite an increase in *trans*-10 C18:1 in milk fat (Chilliard et al., 2003).

Our results indicate that the positive effect of ESB may solve the problem of low milk fat content, which may be lower than milk protein content, as often observed in midlactation goats during spring and summer (Morand-Fehr et al., 2000). Moreover, feeding ESB had no detrimental effect on the milk protein content or protein yield as observed with dairy goats by Daccord (1987). Again, this indicates species differences, as supplemental fat often decreased the milk protein content in lactating dairy cows (De Peters and Cant, 1992). This latter point is of great importance because goat milk is almost exclusively made into cheese, in which quality is partly affected by milk protein content (Brown et al., 1995).

Feeding ESB dramatically decreased the proportions of medium-chain saturated FA in milk fat, as reported by Schmidely and Sauvant (2001). This was observed for all saturated FA having 10 to 17 carbon units (straight or branched, even or odd numbered), and the decrease was linearly related to the percentage of incorporation of ESB in the diet. Although these results were in line with those reported in dairy cows (Dhiman et al., 1999; Abu-Ghazaleh et al., 2002; Whitlock et al., 2002), the reduction in medium-chain saturated FA percentage in our experiment was higher than in dairy cows, probably because of a greater incorporation of ESB (20% for the 20% ESB diet) in the DM of the diets. This reduction in medium-chain FA concentration was probably due to the increase in dietary long-chain FA by ESB, which has been shown to inhibit de novo medium-chain FA synthesis in the mammary gland (Barber et al., 1997). This sharp decrease in medium-chain FA in milk fat of the goats fed the ESB diet and the decrease in the saturated to unsaturated fat ratio may be favorable for humans from a nutritional point of view, because the medium-chain FA are an important part of the hypercholesterolemic portion of milk fat (Hu et al., 1997).

When the 20% ESB diets were compared with the control diet for long-chain FA concentration in milk fat, the stearic acid concentration in milk fat was more than twice as high, probably because of its high content in the diet, whereas oleic acid concentration was only increased by 40%. In the mammary gland of ruminants (Chilliard et al., 2003), monounsaturated FA arise from direct uptake from the blood, or from desaturation of saturated FA via a $\Delta^9$-desaturase (stearoyl-CoA desaturase). The C14:0, C16:0, and C18:0 FA are substrates for $\Delta^9$-desaturase in the mammary gland that introduces a double bond to produce *cis*-9 C14:1, *cis*-9 C16:1, and *cis*-9 C18:1. Consequently, product to substrate ratio of *cis*-9 C18:1 to C18:0 represents a desaturase index and serves as a proxy for $\Delta^9$-desaturase activity. In our trial, feeding ESB reduced the desaturase index of goat milk fat (–50% in average) as observed in dairy cows (Abu-Ghazaleh et al., 2002; Whitlock et al., 2002). This reduction in desaturase index of milk fat has been attributed to the increase in long-chain polyunsaturated FA (Chilliard et al., 2000), or to the increase of the *trans*-10,*cis*-12 C18:2 isomer of conjugated linoleic acid (Baumgard et al., 2000). Indeed, linoleic acid (n-6) concentration in milk fat of goats was linearly increased with the percentage of ESB in this study, but conjugated linoleic acids were not determined.

Compared with goats fed the control diets, the linoleic acid (n-6) concentration in milk fat was more than doubled, whereas linolenic acid (n-3) was only slightly increased in the milk fat of goats fed the ESB diets. Similar results were observed in dairy goats fed soybean oil (Baldi et al., 1992), although the higher increase in linoleic acid in our study suggests that linoleic FA from ESB might have been less subjected to biohydrogenation in the rumen than FA from soybean oil. This increase in the proportion of long-chain polyunsaturated fatty acids (particularly n-3) in milk fat is interesting for human nutrition and health because long-chain polyunsaturated fatty acids stimulate the immune system and reduce the frequency of cardiovascular diseases and some cancers (Spector, 1999). However, this is partly counterbalanced by the increase in the n-6 to n-3 ratio in the milk fat of the goats fed the ESB diets.

### Buffer Addition

In our trial, the addition of sodium bicarbonate did not modify DMI, as reported in goats (Hadjipanayiotou, 1982) and dairy cows (Kennelly et al., 1999; Khorasani and Kennelly, 2001), but in contrast to other data in goats (Hadjipanayiotou, 1988). These differences can be related to the variations in ruminal pH. In the study of Hadjipanayiotou (1988), pH was largely increased by the addition of sodium bicarbonate (+0.4 units), whereas it was not the case in the other studies mentioned above or in our trial (+0.05 units). With high-concentrate diets, no increase or a small increase in rumen pH was reported in dairy cows (Kennelly et al., 1999; Khorasani et Kennelly, 2001) and sheep (Hadjipanayiotou, 1982) but this was not always the case in dairy cows (Kalscheur et al., 1997) or in goat kid (Hadjipanayiotou, 1988). The changes in ruminal pH to the addition of buffer were related to the forage-to-concentrate ratio of the diet, to the intrinsic buffering capacity of the forages, or to ruminal pH before feeding (Erdman, 1988). In our trial, the forage-to-concentrate ratio was 70%, which is the threshold considered for sodium bicarbonate to be effective in increasing pH (Erdman, 1988). Moreover, the ruminal pH before feeding was not very low, which may explain the low efficiency of bicarbonate to prevent the drop in pH.

Sodium bicarbonate increased the total rumen VFA concentrations, and the molar proportion of acetate in the rumen, and numerically increased the acetate to propionate ratio, which is in agreement with data in cows and goats with a similar inclusion of buffer (Hadjipanayiotou, 1988; Kalscheur et al., 1997). However, this increase in the molar acetate percentage is probably not sufficient to account for the large increase in milk fat content (an average of 3.4 g/kg) observed in the goats fed bicarbonate. Indeed, the addition of buffer can be considered an efficient tool to prevent low milk fat content in midlactation goats fed high-concentrate diets (despite a low efficiency in reducing the pH drop after the meal) and to increase the acetate to propionate ratio. In dairy cows, Khorasani and Kennelly (2001) calculated that acetate to propionate ratio variations only accounted for 36% of the variation in milk fat content. The effects of bicarbonate on milk yield and milk protein content were not significant as observed in dairy females fed high-concentrate diets (goats: Hadjipanayiotou, 1982; dairy cows: Khorasani and Kennelly, 2001). Similarly, addition of buffer had no major effect on FA proportion in milk fat as observed in dairy cows (Kennelly et al., 1999; Khorasani and Kennelly, 2001).

## CONCLUSIONS

Feeding 20% extruded soybeans in the DM of a high-concentrate diet did not alter negatively DM intake and fermentations in the rumen of midlactation goats. It improved milk production, and milk fat yield and content, without a negative effect on milk protein yield. Feeding extruded soybeans decreased the proportions of saturated fatty acids in milk fat, and increased long-chain polyunsaturated fatty acids, which resulted in an increase in the nutritional value of fat.

The addition of bicarbonate (1% of DM) increased milk fat content without any modification of milk performance, or milk fat composition. It can be used in addition with extruded soybeans to prevent milk fat depression in goats fed high-concentrate diets.

## ACKNOWLEDGMENTS

We thank J. Tessier and the team of the 'Unité Mixte de Recherches' of Grignon for care of the goats and assistance in obtaining research data.

## REFERENCES

Abu-Gazaleh, A. A., D. J. Schingoethe, A. R. Hippen, and L. A. Whitlock. 2002. Feeding fish meal and extruded soybeans enhances the conjugated linoleic acid (CLA) content of milk. J. Dairy Sci. 85:624–631.

Allen, M. S. 2000. Effect of diet on short-term regulation of feed intake by lactating dairy cattle. J. Dairy Sci. 83:1598–1624.

Baldi, A., F. Cheli, C. Corino, V. DellOrto, and F. Polidori. 1992. Effect of feeding calcium salts of long chain fatty acids on milk yield, milk composition and plasma parameters of lactating goats. Small Rumin. Res. 6:303–310.

Barber, M. C., R. A. Clegg, M. T. Travers, and R. G. Vernon. 1997. Lipid metabolism in the lactating mammary gland. Biochim. Biophys. Acta 1347:101–126.

Baumgard, L. H., B. A. Corl, D. A. Dwyer, A. Saebo, and D. E. Bauman. 2000. Identification of the conjugated linoleic acid isomer that inhibits milk fat synthesis. Am. J. Physiol. Regul. Integr. Comp. Physiol. 278:R179–R184.

Brown, J. R., A. J. R. Law, and C. H. Knight. 1995. Changes in composition of goat's milk during the course of lactation: Physiological inferences and technological implications. J. Dairy Res. 62:431–439.

Calderon, I., E. J. DePeters, N. E. Smith, and A. A. Franke. 1984. Composition of goat's milk: Changes within milking and effect of a high concentrate diet. J. Dairy Sci. 67:1905–1911.

Chilliard, Y., A. Ferlay, R. M. Mansbridge, and M. Doreau. 2000. Ruminant milk fat plasticity: Nutritional control of saturated, polyunsaturated, trans and conjugated fatty acids. Ann. Zoot. 49:181–205.

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.

Daccord, R. 1987. Effect of addition of animal or vegetable fat to a hay based on digestibility and nitrogen balance in the lactating goat. Ann. Zoot. 36:329A.

DePeters, E. J., and J. P. Cant. 1992. Nutritional factors influencing the nitrogen composition of bovine milk: A review. J. Dairy Sci. 75:2043–2070.

Dhiman, T. R., E. D. Helmink, D. J. McMahon, R. L. Fife, and M. W. Pariza. 1999. Conjugated linoleic acid content of milk and cheese from cows fed extruded oilseed. J. Dairy Sci. 82:412–419.

Erdman, R. A. 1988. Dietary buffer requirements of the lactating dairy cow: A review. J. Dairy Sci. 71:3246–3266.

Gulati, S. K., E. B. Byers, Y. G. Byers, J. R. Ashes, and T. W. Scott. 1997. Effect of feeding different fat supplements on the fatty acid composition of goat milk. Anim. Feed Sci. Technol. 66:159–164.

Hadjipanayiotou, M. 1982. Effect of sodium bicarbonate and of roughage on milk yield and milk composition of goats and on rumen fermentation of sheep. J. Dairy Sci. 65:59–64.

Hadjipanayiotou, M. 1988. Effect of sodium bicarbonate on milk yield and milk composition of goats and on rumen fermentation of kids. Small Rumin. Res. 1:37–47.

Hu, F. B., M. J. Stampfe, J. E. Manso, E. Rimm, G. A. Colditz, B. A. Rosne, C. H. Hennekens, and W. C. Willett. 1997. Dietary fat intake and the risk of coronary hearth disease in women. N. Engl. J. Med. 337:1491–1499.

INRA. 1989. Ruminant Nutrition. Recommended Allowance and Feed Table. R. Jarrige, ed. Inst. Natl. Rec. Agron., Paris, France.

INRA-AFZ. 2002. Tables de composition et de valeur nutritive des matières premières destinées aux animaux d'élevage. D. Sauvant, J. M. Perez, and G. Tran, ed. Inst. Natl. Rec. Agron., Paris, France.

Kalscheur, K. F., B. B. Teter, L. S. Piperova, and R. A. Erdman. 1997. Effect of dietary forage concentration and buffer addition on duodenal flow of *trans*-C18:1 fatty acids and milk fat production in dairy cows. J. Dairy Sci. 80:2104–2114.

Kennelly, J. J., B. Robinson, and G. R. Khorasani. 1999. Influence of carbohydrate source and buffer on rumen fermentation characteristics, milk yield, and milk composition in early-lactation Holstein cows. J. Dairy Sci. 82:2486–2496.

Khorasani, G. R., and J. J. Kennelly. 2001. Influence of carbohydrate source and buffer on rumen fermentation characteristics, milk yield, and milk composition in late lactation cows. J. Dairy Sci. 84:1707–1716.

Kristensen, N. B., S. G. Pierzynowski, and A. Danfaer. 2000. Net portal appearance of volatile fatty acids in sheep intraruminally infused with mixtures of acetate, propionate, isobutyrate, butyrate, and valerate. J. Anim. Sci. 78:1372–1379.

Ledoux, M., A. Rouzeau, P. Bas, and D. Sauvant. 2002. Occurrence of trans-C18:1 fatty acid isomers in goat milk: Effect of two dietary regimens. J. Dairy Sci. 85:190–197.

Morand-Fehr, P., J. Tessier, F. Meschy, and D. Sauvant. 2000. Effect of roughage level and source in diets on the risk of reversing fat and protein percentages in goat milk. Cah. Options Méditerr. 52:115–118.

National Research Council. 1981. Nutrients Requirements of Goats: Angora, Dairy, and Meat Goats in Temperate and Tropical Countries. Natl. Acad. Sci., Washington, DC.

Piperova, L. S., B. B. Teter, I. Bruckental, J. Sampugna, S. E. Mills, M. P. Yurawecz, J. Fritsche, K. Ku, and R. A. Erdman. 2000. Mammary lipogenic enzyme activity, trans fatty acids and conjugated linoleic acids are altered in lactating dairy cows fed a milk fat-depressing diet. J. Nutr. 130:2568–2574.

Santini, F. J., C. D. Lu, M. J. Potchoiba, J. M. Fernandez, and S. W. Coleman. 1992. Dietary fiber and milk yield, mastication, digestion, and rate of passage in goats fed alfalfa hay. J. Dairy Sci. 75:209–219.

SAS/STAT User's Guide. Release 8 edition 2000. SAS Inst. Inc., Cary, NC.

Schmidely, P., P. Bas, A. Rouzeau, and D. Sauvant. 2001. Influence of extruded soya seeds and sodium bicarbonate on fatty acid composition of milk fat in dairy goats. Renc. Rech. Rumin. 8:99A.

Schmidely, P., and D. Sauvant. 2001. Fat content yield and composition of milk in small ruminants: Effects of concentrate level and addition of fat. INRA Prod. Anim. 14:333–352.

Spector, A. A. 1999. Essentiality of fatty acids. Lipids 34 (Suppl.):S1–S4.

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.

Wheatherburn, M. W. 1967. Phenol-hypochlorite reaction for determination of ammonia. Anal. Chem. 38:971–977.

Whitlock, L. A., D. J. Schingoethe, A. R. Hippen, K. F. Kalscheur, R. J. Baer, N. Ramaswamy, and K. M. Kasperson. 2002. Fish oil and extruded soybeans fed in combination increase conjugated linoleic acids in milk of dairy cows more than when fed separately. J. Dairy Sci. 85:234–243.