Journal of Dairy Research (1999) **66** 177–191 *Printed in the United Kingdom*

Effects of calcium soaps and rumen undegradable protein on the milk production and composition of dairy ewes

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(*Received 16 October 1997 and accepted for publication 6 October 1998*)

Summary. Forty-eight Manchega dairy ewes were used during a complete lactation in a 2×2 factorial design to determine the effects of supplementing diets with fat (calcium soaps of palm oil fatty acids, CSFA) and rumen undegradable protein (RUP) on milk production and composition. Factors tested were amounts of CSFA (0 or 200 g/kg) and RUP (300 or 450 g/kg crude protein) in the concentrate. RUP was altered by adding a mixture of maize gluten meal and blood meal. Lactation was divided into one nursing period (period 1, weeks 1–4), and three milking periods (periods 2–4, weeks 5–8, 9–14 and 15–21). Concentrates were given at 0·8 kg/d during periods 1 and 2, and at 0·6 kg/d in periods 3 and 4. Ewes grazed rotationally in an Italian rye-grass pasture and received a daily supplement of 0·8 kg vetch–oat hay during period 1, and 0·3 kg lucerne hay during periods 2–4. For the whole lactation, supplemental fat markedly increased milk fat content (+23%) and yield (+16%), and decreased milk protein content (−9%). The positive effect of feeding CSFA on milk fat content was more evident at the beginning of lactation; however, its negative effect on milk protein was more pronounced in late lactation. Supplementary RUP had little effect, increasing milk protein content only in period 3, when the crude protein content of pasture was lower. Milk yield and lamb growth were not affected by dietary treatments. The results indicated that CSFA can be useful for increasing the milk fat content of dairy ewes at pasture, which may help farmers to produce milk reaching the minimum requirements of fat content for the cheese industry.

In the Mediterranean system of dairy sheep production, milk fat content is one of the most important factors affecting milk price because of the high fat content of cheeses manufactured with ewes' milk. For Spanish Manchego cheese, milk containing < 80 g fat/kg is subject to penalties (Caja & Such, 1991). In practice, this level of fat content is often difficult to attain with dairy ewes during the first half of lactation because their diets rely heavily on concentrates. The use of calcium soaps of fatty acids (CSFA) has been shown to increase milk fat content in nursing ewes (Pérez Hernández *et al*. 1986; Horton *et al*. 1992; Espinoza *et al*. 1998). However, diets high in fat can lower milk protein content (Kovessy *et al*. 1987; Horton *et al*.

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1992). On the other hand, increasing the rumen undegradable protein (RUP) in the diet results in increased milk production (Robinson *et al.* 1979; Loerch *et al.* 1985) and, sometimes, milk protein content (González *et al.* 1984). For cows, increasing the total amount of dietary amino acids reaching the small intestine by using high RUP sources (DePeters & Palmquist, 1990) or rumen-protected amino acids (Chow *et al.* 1990) may partly alleviate the milk protein depression associated with supplemental dietary fat.

The objective of this experiment was to study the effects of dietary CSFA and RUP in the concentrate on milk yield and composition of dairy ewes as well as on lamb growth.

MATERIALS AND METHODS

Animals and management

Forty-eight Manchega dairy ewes were studied over a complete lactation in a 2 × 2 factorial design. Ewes were blocked by previous milk production, expected number of lambs, and body weight and condition score at the end of gestation, and randomly assigned to four experimental groups. Before mating, ewes were treated with intravaginal progestagen pessaries (Chrono-gest; Intervet, E-37080 Salamanca, Spain) to synchronize oestrus and reduce the variation in lambing dates. The expected number of lambs was assessed 2 months after mating, using real-time ultrasonic scanning (Diasonics, Sonotron, E-08017 Barcelona, Spain).

Ewes were managed in a semi-confined system at the experimental farm of the Universitat Autònoma de Barcelona. Ewes were arranged in pens of 12 with head locks in the feed bunk. The flock grazed daily as a single group between 10.30 and 16.30, and hay and concentrate were given as supplements indoors. Ewes lambed within a 3 week period and nursed an average of 1·2 lambs/ewe. Lambs were weaned 4 weeks after parturition, and their ewes were then machine milked twice daily (09.00 and 17.00), using a Casse-type milking parlour (Westfalia Separator Ibérica, E-08400 Granollers, Spain) at 44 kPa vacuum, 120 pulsations/min, and a 50:50 pulsation ratio.

For experimental purposes, lactation was divided into one nursing period (period 1, weeks 1–4) and three milking periods (periods 2–4, weeks 5–8, 9–14 and 15–21).

Experimental diets

Ewes grazed rotationally in a non-irrigated, annual Italian rye-grass pasture with a portable electric fence, and were given daily supplements indoors consisting of the concentrate and 0·8 kg vetch–oat hay during period 1 (winter), 0·3 kg lucerne hay during periods 2–4 (spring and beginning of summer).

Experimental concentrates contained ground barley, dehydrated beet pulp, soyabean meal, lucerne hay, urea, vitamins and minerals (Table 1) and included different levels of CSFA (0 or 200 g/kg) and RUP (300 or 450 g/kg crude protein). Concentrates that were high in inert fat were obtained by replacing ground barley by palm oil CSFA (Norel SA, E-28007 Madrid, Spain) and rice hulls. The soyabean meal and ground barley in the low RUP concentrates were partly replaced by maize gluten meal, blood meal and ground maize in the high RUP concentrates. Maize gluten and blood meals were used as sources of methionine and lysine respectively.

Dietary treatments started 2 ± 1 weeks prior to parturition at a rate of 0·5 kg concentrates offered once daily before grazing. During lactation, concentrates were offered twice daily in the milking parlour. Ewes received 0·8 kg/d during periods 1 and 2, and 0·6 kg/d during periods 3 and 4, according to the values calculated using

Table 1. *Ingredients and chemical composition of concentrates offered to dairy ewes in these experiments*

	Treatments			
	Low RUP		High RUP	
	No CSFA	200 g CSFA/kg	No CSFA	200 g CSFA/kg
Ingredient, g/kg				
CSFA†	—	200	—	200
Ground barley	623	322	264	259
Ground maize	—	—	223	—
Dehydrated beet pulp	100	135	200	200
Soyabean meal	157	243	78	138
Maize gluten meal	—	—	100	100
Blood meal	—	—	20	20
Lucerne hay	81	—	76	5
Rice hulls	—	67	—	43
Urea	3	3	3	3
Limestone	6	—	3	—
Dicalcium phosphate	16	—	20	—
Disodium phosphate	—	15	—	18
White salt	10	10	10	10
Calcium sulphate	3	4	2	3
Mineral–vitamin mix‡	1	1	1	1
Component				
Dry matter (DM), g/kg	885	906	885	905
Organic matter, g/kg DM	936	898	935	899
Crude protein (CP), g/kg DM	198	200	218	222
RUP, g/kg CP§	303	325	450	432
Crude fibre, g/kg DM	90	101	81	81
Ether extract, g/kg DM	25	34	22	38
HCl–ether extract, g/kg DM	33	185	29	190
Net energy for lactation, MJ/kg DM§	7·53	9·84	7·41	9·88

RUP, rumen undegradable protein; CSFA, calcium soaps of long chain fatty acids from palm oil (Norel SA, E-28007 Madrid, Spain).

† Containing DM, 969 g/kg; fat, 844 g/kg DM; ash, 156 g/kg DM; Ca, 90 g/kg DM; fatty acids (g/kg) 14:0, 15; 16:0, 440; 18:0, 50; 18:1, 400; 18:2, 95.

‡ Containing I, 1·22 g/kg; Mn, 103 g/kg; Zn, 104 g/kg; Fe, 130 g/kg; Cu, 16·6 g/kg; Co, 0·3 g/kg; Se, 0·31 g/kg; vitamin A, 3·21 mg/g; vitamin D, 67·5 μg/g; vitamin E, 62 μg/g; antioxidant, 222 g/kg.

§ Calculated from National Research Council (1989) values.

INRAtion v. 2.01 software (Institut National de la Recherche Agronomique–Centre National d'Etudes et de Ressources en Technologie Avancée, F-2100 Dijon, France). From the feed offered at the barn, the observed milk yield and changes in the body condition score of the ewes, the forage:concentrate ratio ingested was estimated as 60:40 for periods 1 and 2, and 70:30 for periods 3 and 4. Using INRAtion, we calculated that during the nursing period the rations supplied 85–95% of recommended energy levels and 95–100% of protein requirements, depending on treatment. After weaning, the level of nutrients supplied by the rations was estimated to be 100% or more of recommendations.

Measurements, sampling and analyses

Ewes' milk yield during nursing was estimated using the oxytocin method of Doney *et al.* (1979) as modified by Peris *et al.* (1996). Once a week, ewes were separated from their lambs and hand milked twice with a 4 h interval after

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intravenous injections of 4 i.u. oxytocin (Veterin lobulor; Laboratorios Andreu, E-08022 Barcelona, Spain). Milk secretion during this 4 h was assumed to be the normal rate of milk secretion and was extrapolated to 24 h to estimate daily milk yield. A milk sample was taken from the second milking for chemical analysis. Milk yield during milking was measured weekly during two consecutive morning and afternoon milkings, up to 21 weeks in milk or 200 ml/d per ewe, whichever came first. Milk was sampled biweekly with a proportional composite of the morning and afternoon milkings. Milk samples were preserved with potassium dichromate (1 drop of a 70 mg/l solution in 200 ml milk) and stored at 4 °C. Milk was analysed for fat (Gerber method), crude protein (Kjeldahl N × 6·38; Tecator, S-263 01 Höganäs, Sweden), and dry matter (102 °C, 24 h), following the procedures of Association of Official Analytical Chemists (1984). The yield of energy-corrected milk (to 4·31 MJ/kg) was calculated using the formula for Manchega dairy ewes of Molina *et al.* (1991).

$$\text{Energy-corrected milk (kg)} = (0{\cdot}011 \times \text{fat content (g/kg)} + 0{\cdot}4) \times \text{milk yield (kg)}.$$

Samples were taken monthly for hay and concentrates and biweekly for the Italian rye-grass pasture. A subsample was dried at 103 °C for 24 h to determine dry matter, and the rest was ground through a 1 mm screen and analysed for ash, crude protein, crude fibre and fat by ether extraction (Association of Official Analytical Chemists, 1984). The Italian rye-grass was preconditioned at 70 °C for 24 h. In addition, acid hydrolysis–ether extract was determined in the concentrates by mild boiling in 3 M-HCl for 1 h.

Chemical analysis indicated a lower organic matter and a higher HCl–ether extract in the concentrates containing CSFA (Table 1). The energy value of concentrates, estimated from National Research Council (1989) tables, increased from 7·45 to 9·88 MJ net energy for lactation/kg dry matter for control and CSFA concentrates respectively. Owing to the addition of gluten meal and blood meal, the crude protein content increased from 200 g/kg in the low RUP concentrate to 220 g/kg in the high RUP concentrate. Estimated averages of RUP content (National Research Council, 1989) were 314 and 441 g/kg (crude protein basis) for the low and high RUP concentrates respectively.

The chemical composition of the Italian rye-grass varied (Table 2) with time owing to changes in the stage of plant maturity, resulting in a decrease in protein and an increase in fibre content from periods 1 and 2 to 4. The vetch and oat hay was of an average quality and representative of the forage produced in the area.

Body weight (BW) and condition score were measured weekly. Body condition score followed the method of Russel *et al.* (1969) and was measured in a range from 0 to 5 taking into account half points.

Statistical analyses

Results of milk yield and composition, and BW and condition score of ewes were subjected to least squares analysis of variance for factorial designs, using the General Linear Model repeated measures procedure (SAS, 1985) to allow for the within-animal correlation between measurements over time. Week of lactation (1–21) was taken as a time parameter. The model used was

$$Y_{ijk} = m + P_i + F_j + (PF)_{ij} + e_{ijk},$$

where Y is the dependent variable, m the overall mean of the population, P the mean effect of RUP, F the mean effect of CSFA, and e the unexplained residual error.

Table 2. *Composition of dietary forages given to dairy ewes during experimental periods*†

	Forage				
	Vetch–oat hay	Lucerne hay	Italian rye-grass pasture		
Period …	1	2–4	1–2	3	4
Dry matter (DM), g/kg	911	942	182	176	212
Organic matter, g/kg DM	928	907	890	909	910
Crude protein, g/kg DM	82	150	119	83	83
Crude fibre, g/kg DM	370	374	184	217	319
Ether extract, g/kg DM	11	10	24	21	24
N-free extract, g/kg DM	465	373	563	590	484

† Period 1, nursing: weeks 1–4 post lambing; periods 2, 3 and 4, milking: weeks 5–8, 9–14 and 15–21 respectively. For more details, see text.

Values of lamb growth during nursing were subjected to least squares analysis of variance for factorial designs, using the General Linear Model (SAS, 1985). In this case, the birth BW of lambs was used as a covariable in the model

$$Y_{ijkl} = m + P_i + F_j + (PF)_{ij} + L_k + e_{ijkl},$$

where L was the number of lambs nursed (1 or 2).

RESULTS

Milk production and composition

Milk yield over the whole lactation (Table 3) and during the nursing and milking periods (Table 4) was not affected by dietary treatment. No significant interactions were detected between CSFA supplementation and RUP level. Milk yield curves (Fig. 1) were of the typical pattern described previously for Manchega dairy ewes (Gargouri *et al*. 1993*a*, *b*; Caja, 1994), with a marked drop in production after weaning.

Over the whole lactation, the ewes given CSFA supplements had on average a higher milk fat content than the unsupplemented animals (Fig. 2*a*), the difference being significant (+18·3 g/l, $P < 0·001$). An interaction ($P < 0·001$) between CSFA and time (i.e. week of lactation) was found over the whole lactation (Table 3) and during the milking period (Table 4), but not during the nursing period. The increase in fat concentration was particularly marked (+24·8 g/l, $P < 0·001$) during the first 8 weeks of the trial (results not shown), the differences being smaller at the end of lactation (Fig. 2*a*). As a result of the higher fat content of the CSFA diets, milk fat yield increased over the whole lactation and during the individual periods ($P < 0·05$), except for period 4 (results not shown). Energy-corrected milk followed the same pattern as milk fat yield, although differences were significant ($P < 0·05$) only during period 3. The addition of RUP sources to the diet tended ($P = 0·06$) to increase milk fat and total solids content in period 4, but did not affect milk fat yield.

Milk protein content was reduced ($P < 0·001$) by the addition of CSFA over the whole lactation (Table 3) and during the milking period (Table 4). The average reduction of milk protein concentration during the complete lactation was about one-third of the increase in milk fat content. As lactation proceeded, milk protein

Table 3. *Least squares means for milk production and composition of dairy ewes given concentrates containing different amounts of rumen undegradable protein (RUP) and calcium soaps of palm oil fatty acids (CSFA) during a complete lactation (weeks 1–21)*

	Treatments									
	Low RUP		High RUP			Main effects, $P <$			Interactions, $P <$§	
	No CSFA	200 g CSFA/kg	No CSFA	200 g CSFA/kg						
n …	12	12	12	12	SEM†	CSFA	RUP	Time‡	Time × CSFA	Time × RUP
Milk, kg/ewe	134·8	136·6	137·2	122·5	10·3	0·42	0·57	0·0001	0·0001	0·30
ECM, kg/ewe‖	169·5	198·6	179·0	184·0	14·0	0·12	0·88	0·0001	0·34	0·03
Fat, g/kg	77·8	96·7	82·8	100·6	2·4	0·0001	0·09	0·0001	0·0001	0·07
Fat, kg/ewe	10·5	13·1	11·3	12·3	0·9	0·02	0·98	0·0001	0·03	0·02
Crude protein, g/kg	60·1	54·1	60·9	56·2	1·3	0·0001	0·19	0·0001	0·0001	0·0008
Crude protein, kg/ewe	7·9	7·3	8·1	6·8	0·6	0·11	0·71	0·0001	0·0009	0·77
Milk solids, g/kg	189·8	201·9	194·6	206·6	3·0	0·0004	0·14	0·0001	0·0001	0·0001
Milk solids, kg/ewe	25·6	27·4	26·6	25·3	1·9	0·64	0·66	0·0001	0·21	0·16

† Overall standard error of the mean for 48 ewes.
‡ Time, i.e. week of lactation.
§ Interactions RUP × CSFA and CSFA × RUP × time were not significant.
‖ Energy-corrected milk, to 4·31 MJ/kg, kg/ewe (= milk yield (kg/ewe) × (0·011 × fat content (g/kg) + 0·4)) (Molina *et al.* 1991).

Table 4. *Least squares means for milk yield and composition of dairy ewes given concentrates containing different amounts of rumen undegradable protein (RUP) and calcium soaps of palm oil fatty acids (CSFA) during nursing (weeks 1–4) and milking (weeks 5–21)*

	Treatments									
	Low RUP		High RUP			Main effects, $P <$			Interactions, $P <$§	
	No CSFA	200 g CSFA/kg	No CSFA	200 g CSFA/kg						
n …	12	12	12	12	SEM†	CSFA	RUP	Time‡	Time × CSFA	Time × RUP
Nursing										
Milk, kg/d	1·63	1·57	1·81	1·53	0·14	0·22	0·61	0·18	0·001	0·87
ECM, kg/d‖	1·98	2·29	2·21	2·37	0·20	0·24	0·36	0·15	0·08	0·38
Fat, g/kg	73·9	96·6	74·1	103·5	3·6	0·0001	0·31	0·04	0·32	0·06
Fat, g/d	120·2	151·5	135·2	160·2	14·1	0·04	0·30	0·097	0·29	0·27
CP, g/kg	52·2	50·2	51.4	49·8	1·1	0·09	0·54	0·0001	0·06	0·18
CP, g/d	85·4	78·2	91·7	74·9	7·0	0·07	0·80	0·88	0·003	0·97
Milking										
Milk, kg/d	0·75	0·78	0·73	0·67	0·06	0·82	0·32	0·0001	0·05	0·06
ECM, kg/d	0·95	1·13	0·96	1·00	0·09	0·14	0·48	0·0001	0·28	0·01
Fat, g/kg	78·5	96·6	85·0	99·7	2·5	0·0001	0·09	0·0001	0·0001	0·07
Fat, g/d	58·8	74·5	61·2	66·4	5·5	0·03	0·57	0·0001	0·001	0·01
CP, g/kg	61·7	55·4	63·6	58·0	1·5	0·0001	0·13	0·0001	0·0001	0·09
CP, g/d	46·3	42·5	45·9	38·6	3·7	0·19	0·57	0·0001	0·42	0·06

CP, crude protein.
† Overall standard error of the mean for 48 ewes.
‡ Time, i.e. week of lactation.
§ Interactions RUP × CSFA and CSFA × RUP × time were not significant.
‖ Energy-corrected milk, to 4·31 MJ/kg, kg/ewe (= milk yield (kg/ewe) × (0.011 × fat content (g/kg) + 0·4)) (Molina *et al.* 1991).

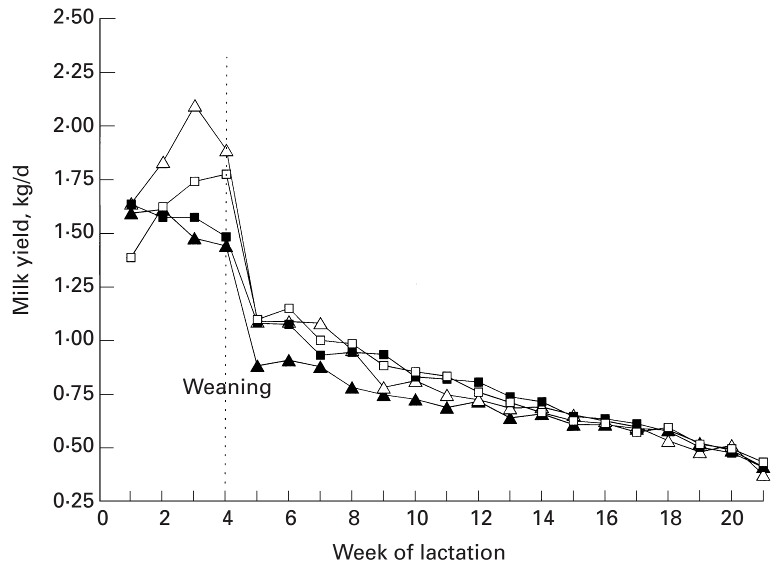

Fig. 1. Effect of adding calcium soaps of palm oil fatty acids and/or rumen undegradable protein to the concentrate supplement on the milk yield of dairy ewes: □, control; ■, calcium soaps; △, high rumen undegradable protein; ▲, calcium soaps plus high rumen undegradable protein.

content progressively decreased, and these changes were significant in periods 2 ($P < 0{\cdot}05$), 3 ($P < 0{\cdot}01$) and 4 ($P < 0{\cdot}001$). Indeed, there was an interaction ($P < 0{\cdot}001$) between CSFA and week of lactation during milking and over the whole lactation (Tables 3 and 4). Supplementary RUP increased ($P < 0{\cdot}05$) milk protein content only during period 3 (results not shown), and no interaction was found between CSFA and RUP. Milk protein yield was not significantly affected by either CSFA or RUP during any period.

As a result of the large increase in milk fat content, diets containing CSFA produced milk with a higher total solids content over the whole lactation ($P < 0{\cdot}001$, Table 3) and during periods 1, 2 and 3 ($P < 0{\cdot}001$, results not shown). The total solids content of the milk was also higher during period 3 ($P < 0{\cdot}05$) for the high RUP diets. No dietary effects were observed in the yield of total solids in milk.

Body weight and body condition score

The average BW at lambing was 53·4 kg and the body condition score 2·9. In general, variations in BW and condition score among treatments were small throughout the trial (Fig. 3). After lambing, body condition score decreased ($P < 0{\cdot}05$) during week 1 only for ewes not receiving CSFA. From lambing to weaning, ewes not receiving CSFA lost more BW (1·15 kg) than ewes given fat supplements, but differences were not significant. After they had been weaned, ewes receiving all treatments recovered BW and condition score. However, at the end of lactation the ewes receiving CSFA supplements had a higher increase in BW (Fig. 3*a*) in accordance with the positive effect ($P < 0{\cdot}05$) of CSFA on BW change during the milking period. Moreover, there was a significant interaction ($P < 0{\cdot}001$) between time (week of lactation) and CSFA, in agreement with the higher recovery of BW of CSFA ewes during the second half of lactation.

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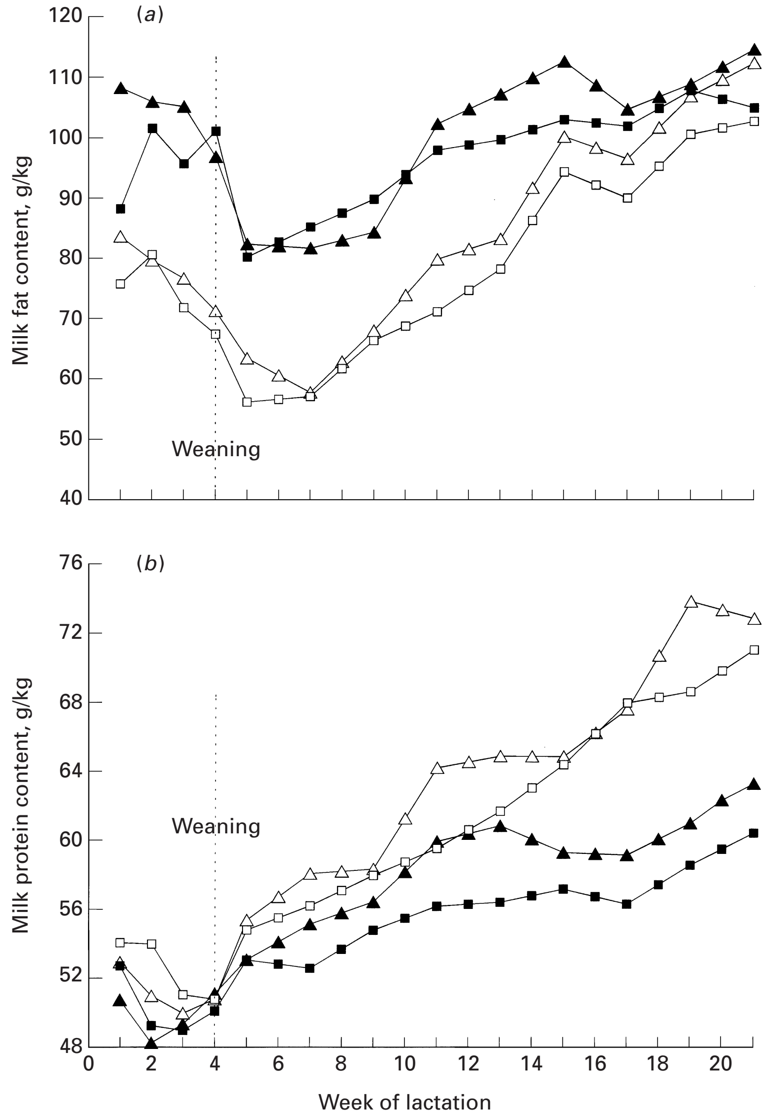

Fig. 2. Effect of adding calcium soaps of palm oil fatty acids and/or rumen undegradable protein to the concentrate supplement on the contents of (*a*) fat and (*b*) protein in the milk of dairy ewes: □, control; ■, calcium soaps; △, high rumen undegradable protein; ▲, calcium soaps plus high rumen undegradable protein.

Lamb growth

Lamb growth was not affected by treatments (Table 5). The increase in milk fat content of ewes given CSFA resulted in only a numerical increase ($P < 0{\cdot}17$) in adjusted weaning weight and average daily gain. However, conversion index (kg BW gained/kg milk) was increased ($P < 0{\cdot}05$).

DISCUSSION

Milk production

The lack of response in milk production to the inclusion of CSFA in the concentrate agrees with previous studies in which no effect of CSFA on the milk yield

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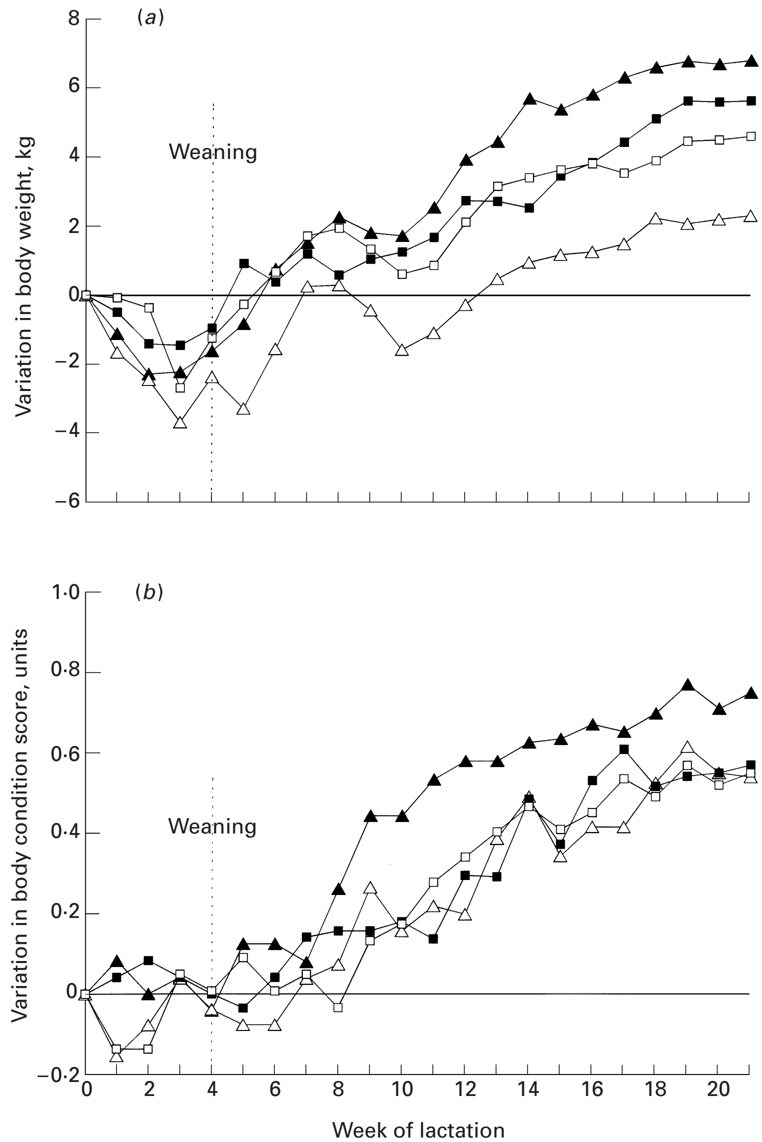

Fig. 3. Effect of adding calcium soaps of palm oil fatty acids and/or rumen undegradable protein to the concentrate supplement on the variation in (*a*) body weight and (*b*) body condition score of dairy ewes: □, control; ■, calcium soaps; △, high rumen undegradable protein; ▲, calcium soaps plus high rumen undegradable protein.

of nursing ewes was found (Pérez Hernández *et al.* 1986; Robinson 1986; Kovessy *et al.* 1987; Horton *et al.* 1992). For dairy cows, milk production responses frequently have been reported in high-producing animals in early lactation (Ferguson *et al.* 1990), but not later in lactation (Schauff & Clark, 1989). Ferguson *et al.* (1990) suggested that CSFA may not increase milk yield in cows that have a high energy intake or enough mobilizable energy to support optimal milk production. In the present experiment, it seems that the extra energy from the higher losses of body condition score during period 1 in ewes not given CSFA (Fig. 3*b*) was enough to maintain in those animals the same level of milk production as in ewes receiving

Table 5. *Least square means for weights and average daily gain of lambs from dairy ewes given concentrates containing different levels of rumen undegradable protein (RUP) and calcium soaps of palm oil fatty acids (CSFA) during nursing (weeks 1–4)*

	Treatments					Main effects, $P <$‡		
	Low RUP		High RUP					
	No CSFA	200 g CSFA/kg	No CSFA	200 g CSFA/kg				
n …	13	15	15	13	SEM†	CSFA	RUP	L§
Birth weight, kg	3·9	3·8	4·0	4·1	0·1			
Weaning weight, kg	10·1	10·8	10·8	11·1	0·2	0·16	0·51	0·05
Average daily gain, g/d	211·5	234·9	231·4	239·1	5·4	0·17	0·43	0·005
Milk conversion‖	0·16	0·20	0·16	0·19	0·01	0·05	0·73	0·007

† Overall standard error of the mean for 56 lambs.
‡ The interaction RUP × CSFA was not significant.
§ No. of lambs nursed by ewe (1 or 2).
‖ Measured as kg lamb gain/kg milk.

CSFA. This suggests that the ewes in the control group were not in severe negative energy balance. In contrast to other reports (Robinson *et al.* 1979; Loerch *et al.* 1985), increased RUP in the diet had no significant effect on milk yield, suggesting that in general the low RUP diet provided enough protein to the small intestine to maximize milk production.

Milk composition

Changes in milk fat content were consistent with previous reports on lactating ewes (Pérez Hernández *et al.* 1986; Kovessy *et al.* 1987; Horton *et al.* 1992) and goats (Baldi *et al.* 1992). However, the impact of CSFA on the milk fat content for ewes was greater than that reported for dairy cows (Chilliard *et al.* 1993), where responses vary considerably and frequently depend on the lipid content of the basal diet. In our case, with forages of low ether extract content, especially during period 1 (Table 1), the increase in milk fat content was particularly marked during the first two periods of the trial (8 weeks) and declined at the end of lactation. A similar pattern has been reported for dairy cows, where increases in milk fat content were significant only in early lactation (Eastridge & Palmquist, 1988; Ferguson *et al.* 1990). Because concentrate intake was greater in periods 1 and 2 (800 g/d) than in periods 3 and 4 (600 g/d), the higher response in milk fat content at the beginning of lactation could be related to a higher fat intake. Variations in the composition of the basal diet during the trial may also have had some influence. However, differences in the efficiency of direct transfer of dietary fatty acids to milk may also be responsible for the interaction found between CSFA and time or week of lactation. Compared with control diets, CSFA diets produced increases in milk fat yield of 228 and 136 g/kg supplemental fat during periods 1 and 2 respectively. The corresponding increases for periods 3 and 4 were of 170 and 153 g/kg. This reduction in the response in milk fat content occurred at the same time as BW and condition scores started to recover, suggesting that at the end of lactation dietary fatty acids were partitioned more towards body fat. Previously, Glascock *et al.* (1983) demonstrated that triacylglycerols were transferred to milk more efficiently at the beginning of lactation and, as lactation advanced, more fatty acids were used for deposition of adipose tissue. Moreover, at the end of lactation ewes receiving CSFA had higher increases in BW, and this could be related to the higher net energy for lactation of CSFA concentrates.

Decreases in milk protein content when CSFA is included in the diet have been reported in nursing ewes (Kovessy *et al.* 1987; Horton *et al.* 1992) and cows (Chilliard *et al.* 1993), but not in goats (Baldi *et al.* 1992). In dairy cows, part of this decrease in protein content has been attributed to a dilution effect consequent on increased milk yield (Doreau & Chilliard, 1997), but this was not so in the present study. Negative effects of dietary fat on milk protein content were more marked in late than in early lactation. Similar results were reported in dairy cows by Casper *et al.* (1990). This could indicate that as lactation proceeds there are metabolic changes that modify the response of the ruminants to supplemental fat, in spite of a possible effect due to changes in the quality of the basal ration.

Supplementary RUP had no effect on milk protein content, except in period 3, probably because most of the time the protein supplied by the rations was in excess of the ewes' requirements. In the particular case of period 3, when concentrate was offered daily and the crude protein content of the Italian rye-grass pasture was lower than in periods 1 and 2, it seems that with high RUP diets the amino acid supply to the small intestine was less limiting than with the control diets. With dairy cows, supplementing the diet with poorly degradable proteins (DePeters & Palmquist, 1990; Cant *et al.* 1991) or rumen-protected amino acids (Canale *et al.* 1990) alleviated the depression in milk protein. However, in other cases (Hoffman *et al.* 1991; Palmquist & Weiss, 1994) no benefit was found in increasing the amino acid supply to the small intestine of cows given supplementary fats.

Because we detected no interaction between CSFA and RUP, results from this experiment do not support the hypothesis that the milk protein depression associated with feeding supplemental dietary fat is caused by a deficiency in available protein in the small intestine. In fact, Doreau & Ferlay (1995) indicated in a review that *in vivo* lipids have little effect on ruminal nitrogen metabolism or microbial protein synthesis. Thus, our results seem to be in agreement with findings by Cant *et al.* (1993*a*, *b*) indicating that changes in milk protein content resulting from giving supplemental fat to lactating dairy cows are due to an energy-dependent reduction in mammary gland blood flow that result in a reduction in the availability of amino acids at the mammary gland.

Lamb growth

Adding CSFA to the concentrate given to dairy ewes during nursing did not affect lamb growth. Similar results have been reported by Horton *et al.* (1992) and Espinoza *et al.* (1998), who found no increase in lamb growth when ewes' diets were supplemented with CSFA. In contrast, Pérez Hernández *et al.* (1986) indicated that lamb weight increased and concentrate consumption by lambs decreased when ewes were given concentrates containing CSFA. In our case, working with very young lambs (< 4 weeks of age), we found only an improvement in the efficiency of use of ewes' milk for meat production, probably due to the higher energy content of the milk. On the other hand, Gargouri (1997) showed that although milk fatty acids have a high digestibility in young lambs, the average daily gain at weaning is correlated more with the protein content of the milk than with its energy content. The lack of response in lamb growth was attributed to changes in the protein:energy ratio of the milk from ewes given CSFA.

As in the present experiment, Loerch *et al.* (1985) and Frey *et al.* (1991) found no significant benefit for lamb growth of additional RUP for nursing ewes. Purroy & Jaime (1995) reported higher daily weight gains in lambs sucking ewes given fishmeal as an RUP source, but this was under conditions of restricted energy allowance. In the present study, energy was not a limiting factor.

In conclusion, the addition of CSFA in diets of lactating ewes resulted in increases in milk fat content and yield, and milk total solids content. These increases were more apparent in the first half of lactation. In contrast, milk protein content was reduced by CSFA, especially at the end of lactation. Increasing dietary RUP levels had only limited effects, increasing the content of milk fat and protein only in some periods during the second half of lactation, when the daily concentrate allowance was reduced and pasture was of lower quality. Including CSFA in the concentrate has proved to be an efficient means of increasing milk fat content with little effect on milk protein content, especially during the first half of lactation.

We thank the Comision Interministerial de Ciencia y Tecnología of Spain (Project CICYT: GAN 443/90) and Norel SA (Madrid) for partial support of this trial. We are also grateful to Rosa Armengol for her technical assistance, to Ramon Costa and barn personnel for management of the ewes, and to Dr Don L. Palmquist for helpful suggestions during the preparation of the manuscript.

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