The ratio between dietary rumen degradable organic matter and crude protein may affect milk yield and composition in dairy sheep

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Abstract

The current ruminant protein systems aim at synchronizing the provision of rumen degradable organic matter (RDOM) and degradable crude protein (RDCP) but no specific information on their optimal ratio for dairy sheep is available. We studied the effect of the ratio of RDOM to RDCP on milk yield and composition, during a summer lactation, in 34 confined Assaf sheep managed under farm condition. Individual feed intake was assessed by using PEG (MW 4000) as external marker of fecal output, and indigestible INDF as internal marker of digestibility. Four total mixed rations contained two levels of RDCP (108 and 117 g/kg DM) and two levels of RDOM (510 and 570 g/kg DM). This resulted in one diet featuring high (5.3), one diet featuring medium (4.8) ratio, and two diets featuring low (4.5) ratio of RDOM to RDCP. Individual DM intake, digestibility, and the daily yields of milk components were not affected by RDOM, RDCP or RDOM/RDCP. High RDOM/RDCP tended ($P < 0.10$) to be associated with higher milk yield, and lower ($P < 0.05$) CP content. The casein/CP ratio and urea-N in milk were lowest when both dietary RDCP and RDOM were low, whereas lactose was highest ($P < 0.05$) when both RDOM and RDCP concentrations were high. Our data suggest that RDOM and RDCP interact on milk composition in a way that is not fully encompassed by the RDOM/RDCP ratio and that the use of this ratio to formulate diets for pre-determined milk composition is not warranted.

Keywords: Ewe milk composition; Rumen degradable organic matter; Rumen-degradable crude protein; Assaf sheep
1. Introduction

The current ruminant protein systems aim at maximizing the provision of microbial protein by synchronizing the provision of rumen degradable organic matter (RDOM) and crude protein (RDCP). The synthesis of microbial crude protein (MCP) in sheep fed a synchronized diet was 10–20% higher than in counterparts fed an asynchronous diet (Sinclair et al., 1993). In ARC (1984), it was anticipated that 200 g microbial protein (MCP)/kg OM digested could be synthesized if adequate supply of nitrogen (N) was available in the rumen. In the PDI system (INRA, 1989), widely used in Mediterranean dairy sheep husbandry, the yield of MCP is assumed to be 145 g/kg RDOM if N is not limiting, or 0.9 of degraded CP if RDOM is not limiting. This duality results in attributing two protein values that can be very different to each feed, which complicates the calculation of rations (see feed tables in INRA, 1989). Verbic et al. (1999) characterized the synchrony of N and OM degradation in feeds by their ratio of RDOM to RDCP, based on the in sacco degradability coefficients of dietary ingredients. The synchrony of energy and nitrogen is generally expressed as an index calculated from ruminal kinetics of release on hourly basis (Witt et al., 1999, 2000; Verbic et al., 1999; Shabi et al., 1998, 1999). Meal patterns are a prominent factor of synchrony/asyncrony. The number of meals is greatly increased by feeding ruminants with totally mixed rations, and ruminal pH and the release rates of nutrients, and, in particular, ammonia, are steadier throughout the day (Owen, 1979). This enables to extrapolate the assessment of ruminal synchrony from an hourly to a daily basis, with minimal risk of error.

Contrary to growing animals that exhibited clear response of improved growth to diets differing in synchrony for the hourly supply of energy and nitrogen in the rumen (Witt et al., 1999), comparisons between performances of lactating ruminants fed synchronous or asynchronous diets have yielded responses from nil to modest (Shabi et al., 1998, in cattle; and Witt et al., 1998, 2000, in sheep) relative to daily yields of milk and milk components (protein, fat and lactose). This can result from asynchrony being buffered by the existence of several inter-exchanging microbial pools delivering RDOM and N-nitrogen at a rate different from that estimated by in sacco experiments (Sauvant, 1997) or by a relatively steady flow of nutrients in animals fed totally mixed rations, promoting synchrony. Plasma urea concentration is higher in ewes offered asynchronous diets (Witt et al., 1998) whence milk urea can be considered as estimator of ruminal synchrony on a daily basis.

Most of sheep milk is manufactured to cheese, and the casein and fat contents have logistic, ecological and economical implications (cost of transport of milk components, cost of disposal of unused whey) of utmost importance for the industry. In Mediterranean countries, sheep are frequently fed with total mixed rations featuring low amounts of roughage, and great amounts of concentrates and agricultural by-products (Molle and Landau, 2002). This is the case for sheep of the Assaf breed that originates from crossbreeding the East Friesland and Awassi milk-sheep in Israel, and has become an important breed of dairy sheep in Europe, and in particular in Spain, where it now represents ca. 20% of the dairy sheep population (Ugarte et al., 2001).

The aim of this study was to evaluate the effect of RDOM/RDCP ratio on the yield of milk and milk components in Assaf dairy sheep fed totally mixed rations.

2. Materials and methods

2.1. Diets, animals, and treatments

Eighty multiparous (2.8 lambings, S.E. 0.23) Assaf ewes that had lambed at the end of June (June 26, S.E. 1 day) were allotted to one of four dietary treatments differing in RDOM/RDCP ratio. Groups were blocked according to milk yield in the previous lactation (339 kg, S.E. 15), milk yield (2.17 kg, S.E. 0.10 kg/day) on day 24 post-partum (day 0 of the experiment), and prolificacy (156%, S.E. 6). The animals were housed in a dust floor open building and managed according to the Israel Council of Animal Care Guidelines (1994).

In each group, a subgroup of ewes was identified in which individual milk composition, feed intake and faecal output were assessed. In order to formulate diets differing in RDOM/RDCP ratio, the degradability of OM and CP in feeds was assessed in situ. Dry-milled (2 mm particle size) samples (5 g) were weighed into 12 cm × 6 cm polyester bags with a 45 μm mean pore size. Bags were introduced serially into the rumen and incubated for 96, 48, 36, 24, 12, 9, 6, or 3 h in the rumen of a dairy cow in mid-lactation fitted with a ruminal cannula and main-
Table 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>H</th>
<th>M1</th>
<th>M2</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vetch hay</td>
<td>0.765</td>
<td>0.765</td>
<td>0.765</td>
<td>0.765</td>
</tr>
<tr>
<td>Wheat silage</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
<td>0.353</td>
</tr>
<tr>
<td>Concentrate of molasses soluble</td>
<td>0.097</td>
<td>0.097</td>
<td>0.097</td>
<td>0.097</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>0.176</td>
<td>0.176</td>
<td>0.176</td>
<td>0.176</td>
</tr>
<tr>
<td>Oat grain</td>
<td>0.200</td>
<td>0.200</td>
<td>0.200</td>
<td>0.200</td>
</tr>
<tr>
<td>Barley grain</td>
<td>0.087</td>
<td>0.087</td>
<td>0.087</td>
<td>0.087</td>
</tr>
<tr>
<td>Corn grain</td>
<td>0.432</td>
<td>0.778</td>
<td>0.432</td>
<td>0.778</td>
</tr>
<tr>
<td>Wheat grain</td>
<td>0.088</td>
<td>-</td>
<td>0.263</td>
<td>-</td>
</tr>
<tr>
<td>Gluten feed</td>
<td>0.445</td>
<td>-</td>
<td>0.160</td>
<td>-</td>
</tr>
<tr>
<td>Soya bean meal</td>
<td>0.131</td>
<td>0.296</td>
<td>0.366</td>
<td>0.435</td>
</tr>
<tr>
<td>Vitamins/minerals</td>
<td>0.054</td>
<td>0.054</td>
<td>0.054</td>
<td>0.054</td>
</tr>
<tr>
<td>Planned intake composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total DM intake (kg)</td>
<td>2.83</td>
<td>2.81</td>
<td>2.96</td>
<td>2.95</td>
</tr>
<tr>
<td>Total OM intake (g/kg)</td>
<td>907</td>
<td>911</td>
<td>910</td>
<td>912</td>
</tr>
<tr>
<td>Crude protein (g/kg)</td>
<td>159</td>
<td>160</td>
<td>177</td>
<td>176</td>
</tr>
<tr>
<td>Rumen-degradable OM (g/kg)</td>
<td>572</td>
<td>509</td>
<td>568</td>
<td>515</td>
</tr>
<tr>
<td>Rumen degradable CP (g/kg)</td>
<td>109</td>
<td>106</td>
<td>119</td>
<td>115</td>
</tr>
<tr>
<td>RDOM/RDCP</td>
<td>5.3</td>
<td>4.8</td>
<td>4.8</td>
<td>4.5</td>
</tr>
</tbody>
</table>

2.2. Feed intake

The amount of TMR provided to each group was daily weighed. Residues were collected on days 16-17, 42-43, 55-56, and dried at 65°C in an aerated oven for 3 days.

The assessment of individual intake was carried out in the same 34 ewes that were subjected to milk composition analysis. Fecal output was evaluated for two periods, coinciding with periods 1 and 2 of milk composition assessment. This was done by using PEG (MW 6000) as external marker of fecal output, analyzed by NIR spectroscopy, as described before in goats (Landau et al., 2002). Ewes were drenched daily with 40 g PEG, in 300 water ml solution, using a de-worming quenching gun for 7 days. Feces were sampled three times (08.00, 12.00, and 17.00) daily on the last day, and dried at 65°C in an aerated oven for 3 days. A calibration curve was built by mixing dry feces collected from each group separately in the pre-PEG period with known amounts of PEG. Spectra were scanned using a Foss NIRSystems 5000 reflectance apparatus (Foss Tecator, Hoganas, Sweden). The determination coefficients \( R^2 \) ranged between 0.984 and 0.995, and the standard error of cross-validation, an estimate of accuracy, was 0.22%.

The digestibility of DM was estimated, using indigestible NDF (INDF) as internal marker (Lippke et al., 1986). The concentrations of the INDF in diets (corrected for refusals) and feces were used to calculate the apparent digestibility of the dietary components; DM, OM and CP. For determination of INDF 5 g samples of dry and pooled feces, diets, and orts samples were weighed into 120 mm × 60 mm polyester bags. Each sample was incubated in duplicates in the rumen of a ruminally cannulated dairy cows in mid-lactation and maintained on a standard diet. Bags were removed from the rumen after 168 h and machine-washed with
cold water. Undigested residues from replicates were pooled and ground to pass a 1 mm sieve. The NDF fraction measured in bag residues according to the method of Van Soest et al. (1991) was assumed to be INDF. For calculation, it was assumed that all sheep consumed all the concentrate distributed at the milking parlour, and that sheep were not able to reach their counterparts’ allowance of concentrate, which is a reasonable assumption. It was also assumed that all sheep in one group selected food in a similar way, i.e., that the percentage and composition of orts were representative of all sheep in one group.

2.3. Milk control and milk composition

Ewes were milked twice daily at 05.00 and 16.00. Milk yield was assessed for all 80 sheep on days 18–20 (period 1), days 34–35 (period 2), days 46–48 (period 3) and days 65–66 (period 4) of the experiment by using an electronic device calibrated for sheep and based on the transmission of near infra-red (NIR) beams through the milk flow. Analysis of the changes in IR beam enables to evaluate milk flow on line and calculate the accumulated quantities (S.C.R. Engineers Ltd. Milking systems, Netanya, Israel).

Milk composition was assessed in nine ewes from L, nine ewes from M1, 10 ewes from M2, and six ewes from H. On the last two milkings of each period milk was sampled, after air-whirling, using Waikato (New Zealand) goat-milk control vessels. Milk was refrigerated immediately and frozen until analyzed. Total CP (6.38 × N) in milk was measured on fresh samples at each milking occasion each experimental period. Casein and whey proteins were separated by a standard method (AOAC, 1990) on fresh skimmed milk samples. Total CP in casein and whey were calculated as 6.38 × N. Crude fat was measured on freeze-dry samples and was transformed to whole milk by multiplying by dry matter content of each sample (AOAC, 1990). The concentration of lactose was determined as described by Shapiro et al. (2002). Milk N-urea concentration was determined according to Coulomb and Favereau (1963).

2.4. Statistics

The effect of time (evening versus morning) of milking on milk yield and composition was assessed, using a model that included the effect of the ratio RDOM/RDCP and its interaction with milking time. The effects of levels of CP and of RDOM, and of RDOM/RDCP on milk yield and composition weighted for evening and morning contributions, BW, and BS, were analyzed using a repeated measurement procedure. In a first step, a bi-factorial model was used, with CP (g/kg), RDOM (g/kg), and their interaction, as main effects with sheep (CP × RDOM) as the term of error; and, in a second step, using a one-way model with the ratio RDOM/RDCP as main effect, and sheep (R) as the term of error (SAS, 1989).

3. Results

Fecal output, DM intake, and DM digestibility were not affected by treatments (Table 2). By comparing actual DM intake (Table 3) to that expected (Table 1), it appears that low RDOM/RDCP was associated with lower—but not significantly—than anticipated feed intake (2.5 kg DM, compared with 2.9 kg), whereas the average intake of DM in the other groups was similar to that anticipated (Table 1). The mean digestibility of DM equaled 0.735, and was not affected by dietary levels of RDCP and RDOM, or their ratio.

Globally, milk yield (Fig. 1), when measured in all 80 ewes, was not affected by RDOM, RDCP or their ratio, but tended (P < 0.10) to be greater in ewes fed H than M1 throughout the experiment, in particular at the two last milk controls (P < 0.05). When measured in the 34 ewes of experimental subgroups (Table 3), treatment effects on milk yield did not reach significance.

Ewes in group H produced milk of lower (P < 0.05) CP concentration than counterparts in other groups.
### Table 3
The effect of different rumen degradable organic matter (RDOM) and crude protein (RDCP) contents, their interaction (I), and of the RDOM/RDCP ratio (R) on overall and experimental milk yield and its composition in ewes: least square means and S.E.

<table>
<thead>
<tr>
<th>RDCP</th>
<th>RDOM</th>
<th>Low</th>
<th>Low</th>
<th>High</th>
<th>High</th>
<th>RDCP</th>
<th>RDOM</th>
<th>I</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDOM/RDCP</td>
<td>H (5.3)</td>
<td>M1 (4.8)</td>
<td>M2 (4.8)</td>
<td>L (4.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk yield (kg/day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All period</td>
<td>2.18</td>
<td>1.61</td>
<td>1.75</td>
<td>1.88</td>
<td>0.18</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Control days</td>
<td>1.95</td>
<td>1.51</td>
<td>1.56</td>
<td>1.79</td>
<td>0.16</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>CP (g/kg)</td>
<td>41.7 b</td>
<td>46.9 a</td>
<td>46.0 a</td>
<td>45.7 a</td>
<td>1.3</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>(g/day)</td>
<td>80.0</td>
<td>68.5</td>
<td>69.3</td>
<td>79.6</td>
<td>6.5</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Casein (g/kg)</td>
<td>31.4</td>
<td>32.1</td>
<td>34.1</td>
<td>33.3</td>
<td>0.9</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>(g/day)</td>
<td>40.8</td>
<td>48.2</td>
<td>53.2</td>
<td>59.6</td>
<td>7.9</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Casein/CP</td>
<td>0.76 a</td>
<td>0.70 b</td>
<td>0.77 a</td>
<td>0.75 ab</td>
<td>0.02</td>
<td>†</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Urea-N (mg/kg)</td>
<td>186 ab</td>
<td>161 b</td>
<td>179 ab</td>
<td>208 a</td>
<td>12</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>†</td>
</tr>
<tr>
<td>(g/day)</td>
<td>379 ab</td>
<td>268 b</td>
<td>306 ab</td>
<td>415 a</td>
<td>63</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>†</td>
</tr>
<tr>
<td>Lactose (g/kg)</td>
<td>39.6 b</td>
<td>41.1 b</td>
<td>44.5 a</td>
<td>40.3 b</td>
<td>1.2</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>†</td>
</tr>
<tr>
<td>(g/day)</td>
<td>77.4</td>
<td>63.7</td>
<td>70.0</td>
<td>74.7</td>
<td>0.7</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Fat (g/kg)</td>
<td>51.2</td>
<td>56.5</td>
<td>53.5</td>
<td>52.8</td>
<td>3.3</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>(g/day)</td>
<td>99.8</td>
<td>85.3</td>
<td>83.5</td>
<td>94.5</td>
<td>11.2</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

1 H and M1 differ at *P* < 0.10.
2 H and M2 differ at *P* < 0.06.
3 *P* < 0.10.
4 *P* < 0.05.

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(Table 3), suggesting that high RDOM/RDCP affects milk protein content negatively. High dietary RDCP tended (*P* < 0.10) to be associated with higher casein content, while high RDOM increased (*P* < 0.05) the casein/total milk CP ratio. However, a significant interaction between them was noted. In other words, the combination of low RDCP and low RDOM (M1) was deleterious to the casein/total milk CP ratio but this was reversed by providing high RDCP. High lactose content was noted when ewes were fed diets high in RDOM and RDCP. Milk fat was not affected by treatments. Interestingly, the daily production of milk CP, casein, lactose, and fat was not affected by dietary treatments. The concentration of N-urea in milk was lowest in the milk of ewes fed low RDCP–low RDOM diet and highest for the high RDCP–low RDOM-fed ewes.

Dietary levels of RDCP and RDOM did not affect BW changes (Fig. 2; 0–40 g/day). Body condition score

![Fig. 1](image1.png)
![Fig. 2](image2.png)
(not shown) decreased, on average, by 0.2 units, and was not affected by treatments.

4. Discussion

4.1. Feed intake and digestibility

In the present study, a lower, though not significantly, value for individual DM intake was noted in ewes fed low RDOM/RDCP diets (Table 2). We are not aware of research into the effect of the RDOM/RDCP on voluntary intake in sheep fed totally mixed rations, but a lower intake associated with low RDOM/RDCP was also reported in a study with dairy cows (Shabi et al., 1998). The lack of effect for dietary CP percentage on the intake of DM that we report here is in agreement with Cannas et al. (1998) who found no effect for dietary CP, ranging from 140 to 210 g/kg DM, on the individual intake of DM in lactating Sarda ewes fed totally mixed rations. Our finding that treatments did not affect DM digestibility (Table 2) is in line with the finding of Witt et al. (1999) that total OM digestibility was not affected by RDOM and RDCP synchrony versus asynchrony.

4.2. Milk yield

The CP content of diets for high yielding milk sheep is controversial. Our data (Table 3) suggest that 160 g of dietary CP/kg DM in Assaf ewes, in accord with Cannas et al. (1998) for Sarda ewes fed totally mixed rations. In addition, we show (Table 3) that ewes fed diets of low or medium RDOM/RDCP—4.5 and 4.8—produced similar milk amounts, in agreement with Witt et al. (1999). In addition, it seems that high RDOM tended to increase milk yield when RDCP was low, but had no effect when RDCP was high (Table 3). The highest level of dietary RDOM/RDCP, i.e., 5.3, was associated with a tendency to produce more milk (Table 3 and Fig. 1). Calculations on data obtained in Chios ewes fed diets with RDOM/RDCP ranging from 5.2 to 6.3 (Hadjipanayiotou, 1992), or in dairy cattle fed diets ranging 5.4–6.0 in RDOM/RDCP (Shabi et al., 1998), do not back this finding. There are two possible explanations for this discrepancy. The first one is that a threshold of RDOM/RDCP for improved milk production exists in a range that is not covered by other studies with dairy sheep in the literature, i.e., 4.8–5.3. Another explanation would be that RDOM/RDCP may have different effects on milk yield in various breeds of sheep.

4.3. Milk composition

The CP content of ewe milk (Table 3) was low in the present study (less than 47 g/kg milk), compared with other individual data for Assaf (52–55 g/kg; Leibovich, 1991) or Lacaune ewes (49 g/kg; Pellegrini et al., 1997) at the same stage of lactation. This was possibly the result of extremely hot conditions in July–September in the coastal plain of Israel, as heat stress reduces milk protein and fat contents in sheep milk (Abdella et al., 1993).

A notable finding of the present study was that ewes fed a diet with high RDOM/RDCP ratio tended to produce more milk (Table 3, Fig. 1) of lower CP content (Table 3), resulting in yields of CP similar to that of other treatments. In other words, high RDOM/RDCP ratio resulted in protein dilution in the milk. In dairy cows, high dietary RDOM affected CP positively, but RDOM/RDCP did not affect milk CP content (Shabi et al., 1998). Our results are in line with Witt et al. (2000) who showed no effect for RDOM/RDCP on daily sheep milk components yield. Cannas et al. (1998) also reported that CP concentration was inversely related to milk volume in Sarda ewes fed high-energy diets varying in CP content. These results may evidently be used differently by actors of the sheep milk industry, depending on the relative value of milk volume and its components. Farmers would favor diets high in RDOM/RDC, under payment scheme based on milk volume, but not under schemes that attribute high commercial weight to milk protein percentage. However, practical implementation of these results into feed tables is questionable, because RDOM and RDCP interact significantly on ewe milk CP (Table 3), as noted before by Cannas et al. (1998) for protein and energy.

The casein concentration and casein/CP ratio figures reported in the present study (Table 3) are the first values published for Assaf sheep, to our knowledge, and they are lower than those reported for Lacaune ewes (37 g/kg; Pellegrini et al., 1997) at the same stage of lactation, but yielding 50% less milk. The casein/CP ratio (0.745) reported here for Assaf ewes was slightly
higher than in Sarda (0.73; Leto et al., 2002), but lower than in Lacaune sheep (0.80; Pellegrini et al., 1997).

Casein is the most important commodity for the cheese industry, but milk payment schemes are based on protein content, assuming a constant ratio of casein to protein. Interestingly, the depressed protein content associated with high RDOM/RDCP was not followed by low casein content (Table 3). If larger scale experiments confirm these results, then the issue of payment based on protein \( (N \times 6.38) \) content must be re-visited.

Dietary RDCP diets tended \( (P < 0.10) \) to be positively associated with milk casein (Table 3) but not with urea-N in milk, showing overall good matching between protein and energy. Low dietary RDOM was deleterious to the casein/CP ratio. We found that this ratio was specially impaired in ewes fed the M1 diet, featuring low RDOM and low RDCP. Because the content of CP in milk was not affected negatively in these ewes, it can be inferred that different RDOM and RDCP combinations may result in differences in the relative availability in the mammary gland of amino acids or peptides for the synthesis of casein or lacto-globulins in milk. Further research is needed to elucidate this point that is important to the industry.

Overall, milk urea-N was relatively low (<208 mg/kg) comparable to that described in Sarda ewes fed total mixed rations (Cannas et al., 1998), lower than values in Lacaune ewes (Pellegrini et al., 1997), and, most importantly, far below the threshold of 560 mg/kg that puts reproductive performance at risk in dairy sheep (Branca et al., 2000). When ewes were fed diets low in RDOM, high RDCP resulted in higher urea-N in milk than low RDCP (Table 3), showing that the energy available in the rumen was limiting microbial protein synthesis, an evidence that effects of asynchrony between OM and N release in the rumen may be found even in sheep fed total mixed rations. On the contrary, in ewes fed high RDOM, no effect of RDCP on urea-N was noted, suggesting that nitrogen availability was not limiting.

The difference in milk lactose concentration between ewes fed M2 or the other diets is puzzling, because lactose determines milk volume osmotically, and is, therefore, very resilient to dietary effects. Such increase must be balanced by changes in Na and K concentration, but data on these minerals are not available for milk in the present study. However, liberal allowance of concentrate was associated with increased lactose in goats (Landau et al., 1993), providing conditions of high dietary RDOM and high RDCP. Lactose content was also positively affected by the dietary concentration of energy in Sarda ewes but, within levels of energy, no effect was found for protein level (Cannas et al., 1998).

Finally, no dietary effect was found for dietary CP on the concentration of fat in ewe milk, in accord with Cannas et al. (1998). No effect for RDOM/RDCP was found either. In contrast, Witt et al. (2000) and Hadjianavaitou (1992) showed negative and positive relationship, respectively between RDOM/RDCP and milk fat concentration.

5. Conclusion

Our data suggest that dietary RDOM, RDCP, and the RDOM/RDCP ratio affect milk composition in sheep. However, they interact in a complex way and the ratio does not make their effect on milk composition explicit enough to be used in routine formulations of diets in dairy sheep.

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