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Effects of nutrition on the composition of sheep's milk

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SUMMARY – It is interesting to optimize milk composition by mean of nutrition because milk yield and milk composition are negatively correlated. Milk fat and protein contents are valuable routine parameters from predicting cheese yield in ewe's milk and this paper focuses on both parameters. Variation coefficients and possibilities of altering milk composition by feeding are high for fat and low for protein and casein contents. The effect of the level of nutrition is reviewed and opposite effects of energy balance on milk fat (negative) and milk protein (positive) are presented. A high level of nutrition will decrease fat and slightly increase milk protein and casein percentages in most cases in dairy sheep. Increase in dietary protein concentration in well-fed ewes has no effect on milk fat or milk protein contents. Feeding with concentrate, which is a valuable mean of increasing energy intake, may depress by its own action the milk fat and protein contents as a result of acidosis if it is in excess. Group-feeding strategies applied to the whole flock are generally poorly efficient in improving milk yield or composition. As lambing dispersion is also a main factor in modifying milk composition, variability in flocks and direct effects of feeding on milk composition are often hidden by the heterogeneity of the groups of ewes. The use of protected fat, protein or amino acids appeares to be an effective method for the improvement of milk quality in dairy ewes. Limited experience is available today on this subject and advantages and drawbacks are not well known, nevertheless its use in dairy ewes should increase in the near future.

Key words: Dairy sheep, feeding, milk composition, fat, protein, casein.

RESUME *– "Effet de la nutrition sur la composition du lait de brebis". Il est intéressant d'optimiser la composition du lait par des moyens nutritionnels compte tenu de la corrélation négative entre quantité et composition du lait. Les teneurs en matières grasses et azotées sont des paramètres de routine valables pour prédire le rendement fromager du lait de brebis. En conséquence, cet article traite essentiellement ces deux paramètres. Les coefficients de variation et les possibilités de modifier la composition du lait par l'alimentation sont élevés pour le taux butyreux et bas pour le taux protéique et la teneur en caséines. L'effet du niveau d'alimentation est passé en revue, et les effets opposés de la balance énergétique sur le taux butyreux (effet positif) et le taux protéique (effet négatif) sont présentés. Un haut niveau d'alimentation décroît le taux butyreux du lait et accroît légèrement le taux protéique et la teneur en caséines dans la plupart des cas chez les brebis laitières. L'augmentation de la teneur en matières azotées du régime chez les brebis bien nourries n'a aucun effet sur les taux butyreux et protéique du lait. L'alimentation à base de concentré qui est un moyen valable d'augmenter l'ingestion d'énergie peut réduire directement les taux butyreux et protéique, conséquence de l'acidose si le concentré est en excès. Les stratégies d'alimentation en lots appliquées à tout le troupeau sont généralement faiblement efficaces pour améliorer la production ou la composition du lait. Comme l'étalement des agnelages est aussi un moyen important pour modifier la composition du lait, la variabilité entre les troupeaux et les effets directs de l'alimentation sur la composition du lait sont souvent masqués par l'hétérogénéité des lots de brebis. L'utilisation de matières grasses de protéines, et d'acides aminés protégés semble être une méthode efficace pour améliorer la qualité du lait des brebis laitières. Une connaissance limitée est disponible aujourd'hui sur ce sujet ; les avantages et inconvénients ne sont pas encore bien connus, cependant l'utilisation de ces produits chez la brebis laitière augmentera dans un futur proche.*

Mots-clés : *Brebis laitière, alimentation, composition du lait, lipides, protéines, caséines.*

Introduction

Lactation curves, in yield and milk composition, are mainly conditioned by several factors including breed, stage of lactation, milking system and feeding in sheep (Flamant and Morand-Fehr, 1982; Treacher, 1983, 1989; Bocquier and Caja, 1993), as well as in other dairy ruminants. Moreover it must be remembered that milk yield and milk composition (fat, protein, casein and serum proteins, but not lactose) are negatively correlated in sheep (Barillet and Flamant, 1977; Barillet and Boichard, 1987; Molina and Gallego, 1994; Fuertes *et al*., 1998), as in other dairy species, indicating the necessity to find a equilibrium between practices that will increase milk yield and will reduce its content. This appears in most cases as a result of an improved management, selection and nutrition. As a consequence, the financial income will result from both the unitary price of milk and its quality.

As ewe's milk is mostly transformed into cheese, its quality is mainly comprised in fat and protein concentrations, as they are valuable routine parameters to predict cheese yield (Pellegrini *et al.*, 1997). In fact, as indicated by Bocquier *et al.* (1997a), the main objectives of the dairy sheep breeder's are to: (i) increase the total milk solids output (cheese quantity); (ii) stabilize the milk composition (fat and protein); and (iii) maintain a high ratio of fat:protein in order to ensure an adequate fat content in cheese, for industrial processing and ripening characteristics.

Among the factors that have to be controlled by breeders, the dairy merit of ewes is very important. Before including milk composition as an objective of selection in Lacaune dairy sheep (Barillet *et al.*, 1993), it was reported (Cottier, 1981) that when individual milk yield was increased by 40%, this was followed by a decline in milk fat (–22%) and milk protein (–11%) contents. Lactation stage of ewes is a main factor in milk yield and composition and therefore, lactation curves including milk yield and composition of different sheep's dairy breeds were widely reported taking into account the effects of its respective production systems (Casu *et al.*, 1983; Fernández *et al.*, 1983; Gallego *et al.*, 1983, 1994; Labussière *et al.*, 1983; Bocquier and Caja, 1993; Caja, 1994; Fuertes *et al.*, 1998). In particular, most dairy sheep's production systems include a short lamb suckling period (3-5 weeks length) and, after weaning, a long milking period (4-8 months), but "suckling-and-milking" can occur simultaneously during the first 2 months of lactation in some breeds (Flamant and Casu, 1978; Caja and Such, 1991; Sheath *et al.*, 1995).

With regard to ewe's milk composition, the lowest values in fat, protein and casein are observed during this "suckling-and-milking" period (Gargouri *et al.*, 1993) or immediately after weaning, rising with stage of lactation afterwards. The inclination of the increasing curves of milk are mainly conditioned by the breed and level of production (Bocquier and Caja, 1993).

Although difficult to control, some environmental factors, such as the length of the day (Bocquier *et al.*, 1997a), can also significantly modify markedly the quality of milk collected in sheep farms and explain the variability of responses of milk composition to ewe's nutrition in practice (Fraysse *et al.*, 1996).

Despite the fact that nutrition effects on milk production and composition are relatively well known in the cow (Rémond, 1985; DePeters and Cant, 1992) and to a lower extent in the goat (Morand-Fehr *et al.*, 1991), the effects of nutrition on milk composition in dairy ewes are only partially known as previously stated (Bocquier and Caja, 1993; Bencini and Pulina, 1997; Bocquier *et al.*, 1997a). The aim of the present paper is to review the known effects of nutrition on milk composition of the dairy ewe, because results obtained in dairy cattle and goat may not be successfully extrapolated to dairy sheep. In addition, as dairy ewes are mostly bred in large flocks, it is also necessary to describe briefly the effect of flock structure (including days in milk and parity) on the composition of bulk milk (Bocquier *et al.*, 1995, 1997a; Fraysse *et al.*, 1996) and the consequences on feeding strategies of dairy ewes.

Effects of the level of nutrition

Level of nutrition, mainly referred to energy level or level of feed intake, is a main factor affecting milk yield and milk composition in dairy ruminants. It is generally accepted that there is a positive relationship between milk yield and nutritional status. Hence, a relatively flat lactation curve with a lower and late peak yield is expected when the supply of nutrients fails during early lactation or in the final stage of pregnancy.

On the contrary, a steeped curve with an earlier and higher peak is obtained if the supply of nutrients is high in early lactation. In many cases effects of nutrition on milk composition are less clear and conditioned to the natural evolution of milk composition with lactation stage and furthermore by induced changes in milk volume. Nutrition in the middle and final stages of lactation mainly affects the persistency coefficient and the reconstitution of body reserves, and only small changes are generally expected on milk yield or composition in late lactation (Bocquier and Caja, 1993). Due to the observed variation coefficients of milk fat and protein content, the possibilities of altering milk composition by feeding are higher for fat than for protein and/or casein contents (Sutton and Morant, 1989).

The specific effects of the level of nutrition on milk composition in dairy ewes are only partially known as previously reviewed by Van Quackebeke *et al*. (1981), Bocquier and Caja (1993) and Bocquier *et al*. (1997a). In this sense, few experiments are based in individual feeding of dairy ewes during the milking period and results obtained in suckling ewes are also taken into account to obtain reliable conclusions. Available references on the effects of different levels of nutrition in lactating ewes are summarized in Table 1.

Table 1. Ranges and sense of variation of milk yield and composition induced by the level of nutrition in lactating ewes

Lactation period and reference	Breed†	Diet		Milk		
		Energy (UFL/d)	Protein (g PDI/d)	Yield (l/d)	Fat (g/l)	Protein (g/l)
Suckling						
Robinson *et al*. (1974)	Cheviot	2.14-2.27	188-265	2.4-3.1	76-74	54-50
Cowan *et al*. (1980)	FxD	1.78-2.77	214-317	2.2-3.3	83-74	55-52
Cowan *et al*. (1981)	FxD	2.28-2.33	241-277	3.3-3.5	84-92	53-56
González *et al*. (1984)	FxD	1.66-2.36	183-260	2.3-2.6	90	50-52
González *et al*. (1984)	FxD	1.66-2.36	212-302	2.3-2.7	90	52-54
González *et al*. (1984)	FxD	1.66-2.36	239-339	2.5-3.1	90	53-54
Geenty and Sykes (1986)	Dorset	1.99-2.00	146	2.4-2.5	76	40-39
Geenty and Sykes (1986)	Dorset	1.51-2.42	138-170	2.0-2.7	79-69	40-39
Pérez-Oguez *et al*. (1994)	Manch.	1.36-1.49	143-162	1.4-1.5	88-84	49
Milking						
Treacher (1971)	Dorset	1.06-2.18	107-221	1.2-1.5	83-68	46-52
Bocquier *et al*. (1985)	FxSxL	0.87-0.95	113-122	1.0	35-52	32
Geenty and Sykes	Dorset	1.83	124	1.7	71	47
Geenty and Sykes	Dorset	1.69-2.10	132-158	1.5-2.0	71-65	53
Pérez-Oguez *et al*. (1994)	Manch.	1.41-1.50	147-164	0.6	92-99	57-58

†FxD = Finnish landrace x Dorset horn; Manch. = Manchega; FxSxL = Finnish x Sarda x Lacaune.

It should be stressed that, in the practical conditions of dairy flock management and as a consequence of group feeding practices, the observed global effects of level of nutrition (over or under-nutrition) are normally hidden inside the feeding treatments and are mainly due to high yielding ewes. Intake of protein and forage: concentrate ratio can differ according to feed intake capacity and in these conditions a careful interpretation of data is recommended.

In most dairy sheep breeds fed good quality forages *ad libitum*, the energy balance reaches the equilibrium within a few weeks after weaning (Caja, 1994; Bocquier *et al*., 1995) as a consequence of the evolution of voluntary intake (Bocquier *et al*., 1987a, 1997b; Pérez-Oguez *et al*., 1994, 1995; Caja *et al*., 1997) and milk yield in dairy ewes. This can be, however, impaired either by the use of large amounts of concentrate which induces a decline in forage consumption (Bocquier *et al*., 1983) or by poor quality forages.

Milk fat content is negatively correlated ($r = -0.87$; $P < 0.05$) to energy balance (–1 UFL/d = +12.2

g/l milk fat), this relationship being established (Bocquier and Caja, 1993) from available references of suckling and milking ewes in a wide range of net energy balance (–1.5 to +1.5 UFL/d) and milk yield (0.6 to 3.5 l/d). Consequently, a high level of nutrition will reduce milk fat percentage in most cases in dairy ewes.

With regard to milk protein content, in accordance with cow and goat conclusions, the relationship is positive ($r = 0.64$; $P < 0.05$) and shows a lower and flatter slope with regard to milk fat. In consequence a high level of nutrition in dairy ewes generally produces a slight increase in milk protein and casein contents. This was also stated in both dairy goats (Flamant and Morand-Fehr, 1982; Morand-Fehr *et al*., 1991) and cows (Rémond, 1985; DePeters and Cant, 1992).

As a general consideration, data on milk composition has allowed a better knowledge of requirements for fitting the production potential of each dairy breed (Treacher, 1971, 1983, 1989; Papas, 1977a,b; Bocquier *et al*., 1987b; Bocquier and Caja, 1993; Caja, 1994) and has improved milk composition in experimental trials or in practice.

Undernutrition

Grazing dairy ewes in typical extensive or semi-intensive systems in the Mediterranean area are periodically subjected to undernutrition, in relation to seasonal changes in forages or by-products availability (Caballero *et al*., 1992; Sheath *et al*., 1995). Moreover, in intensive large flocks of dairy ewes, even when food supply is theoretically assured, stage of lactation and competition for food between ewes often lead to some underfeeding situations, specially in the case of the most productive ewes in early lactation (or rearing twins or triplets) which have higher nutritive requirements (Bocquier *et al*., 1995).

Negative energy balance produced by undernutrition will result in a decrease in milk yield and protein content and in an increase in milk fat, in accordance with values shown in Table 1 and in literature (Flamant and Morand-Fehr, 1982). Slope of regression between milk yield and fat content (–6.3 g/l) estimated by Bocquier and Caja (1993) from available data is higher than observed in the Lacaune population (–4.9 g/l), Barillet and Boichard (1987) indicating that not only dilution-concentration effects are involved in this increase of milk fat content. Increase of blood free fatty acids, as a consequence of body fat mobilization, is an important reason for the observed high milk fat content.

While undernutrition is mostly physiological at the onset of lactation, its effects during middle- or late-lactation are not well documented, neither in dairy ewes (Bocquier and Caja, 1993; Bocquier *et al*., 1997a) nor in cattle (Coulon and Rémond, 1991). During this period, a severe and chronic undernutrition of dairy ewes (Bocquier *et al*., 1990) strongly reduced the milk yield (–31%) and increased milk fat content in +9.6 g/l (+16%), while protein content of milk was unchanged. Prolongation of a moderate undernutrition (80% of energy requirements) at the start of the milking period or a decrease in the nutrition level from high to low, in Lacaune dairy ewes fed with an adequate supply of protein, indicate that milk decline is dependent on medium term energy balance (Table 2) as shown by Bocquier *et al*. (1997a). Variation in milk composition induced by undernutrition was also tempered by previous energy level.

Over-nutrition

Over-nutrition is also a consequence of group feeding in dairy ewes and it is considered to be a normal way to restore the body reserves in the mid- or late-lactation (Bocquier and Caja, 1993). High levels of nutrition after weaning can contribute to achieving positive energy balances in dairy ewes as a consequence of maintaining the high levels of intake as at the end of the suckling period (Pérez-Oguez *et al*., 1994, 1995). As a general trend, if energy supply is increased, milk protein content tends to increase slightly and fat content tends to decrease, as described before.

The expected increment in milk protein content by increasing the level of nutrition during the milking period is very low as shown in Table1 and indicated by Bocquier and Caja (1993). Values are lower than in the suckling period as a consequence of differences in energy balance.

Undernutrition and re-feeding

Given the normal group feeding and step-diet system used on dairy sheep during the full lactation period, it is also of interest to analyze the effects of mid term periods of undernutrition and re-alimentation on milk yield and milk composition. With this aim Bocquier *et al*. (1997a) analyzed the effect of two levels of energy allowances (high or low), in two successive periods of 4 weeks during the start of the milking period in Lacaune dairy ewes.

Table 2. Effects of change of nutrition level on milk yield and composition in dairy ewes during milking period (Bocquier *et al*., 1997a)

Item	Energy level during milking periods (P1-P2)			
	Low-low	High-high	Low-high	High-low
Milk yield (l/d)				
P1	1.52^{bc}	1.99^{a}	1.41^{c}	1.74^{ab}
P2	0.82^{b}	1.26^{a}	0.93^{b}	1.09^{ab}
Difference	0.70 (–46%)	0.73 (–37%)	0.48 (–34%)	0.65 (–37%)
Milk fat (g/l)				
P1	68^{ab}	66^{b}	70^{a}	68^{ab}
P2	80^{a}	75^{a}	76^{a}	78^{a}
Difference	12 (+18%)	9 (+14%)	6 (+9%)	10 (+15%)
Milk protein (g/l)				
P1	50^{a}	48^{b}	50^{a}	48^{ab}
P2	57^{a}	53^{a}	54^{a}	53^{ab}
Difference	7 (+14%)	5 (+10%)	4 (+8%)	5 (+10%)

[a, b, c]Different letters in same line indicate significant differences at $P < 0.05$.

From the first to second period, the feeding treatments were maintained (high-high and low-low) or crossed-over (high-low or low-high). Ewes in high groups were fed 95-105% of total energy requirements, whereas ewes in low groups were fed at 80-85% of their energy requirements. For all groups, the protein supply was above the requirements. Results are summarized in Table 2 and Fig. 1.

In addition to the natural decline in milk yield during lactation, the energy supply changed the persistency of milk yield during the different milking periods. The decline in milk yield was highly and negatively correlated ($r = -0.99$) to the energy supply in percentage of total requirements (Fig. 1), showing the detrimental effect of negative balances in the feeding practice of dairy ewes.

The slope between mean values milk energy output and mean energy deficit for groups of ewes was 0.54 ($P < 0.05$), indicating that mobilization of body reserves reduced the energy deficit by 46%. In a previous experiment the contribution of body reserves to milk energy was also 46% on average (Vermorel *et al*., 1985) and similar to values obtained in dairy cows.

In re-feeding situation (group low-high), the switch from low to high level of nutrition had favorable effects on both persistency and milk composition. This shows, like in dairy cows (Windisch *et al*., 1991) and goats (Morand-Fehr and Sauvant, 1980; Morand-Fehr *et al*., 1991) that negative effect of an energy deficit of a few weeks can be partially restored when animals are re-fed. The fraction of energy oriented toward the production of milk was estimated to be 39% of extra energy supply. In cows, it was concluded (Windisch *et al*., 1991) that nearly 110% of energy requirements are necessary to restore milk production after a period of undernutrition.

It is of interest to notice that the sudden switch of the diet from high to low energy levels and vice versa gave an extra decline of 6% in milk yield (Fig. 1), indicating that too rapid adaptation to new diets can produce a nutritive stress in dairy ewes. For this reason step-feeding changes during lactation, according to milk production level, should be set up carefully.

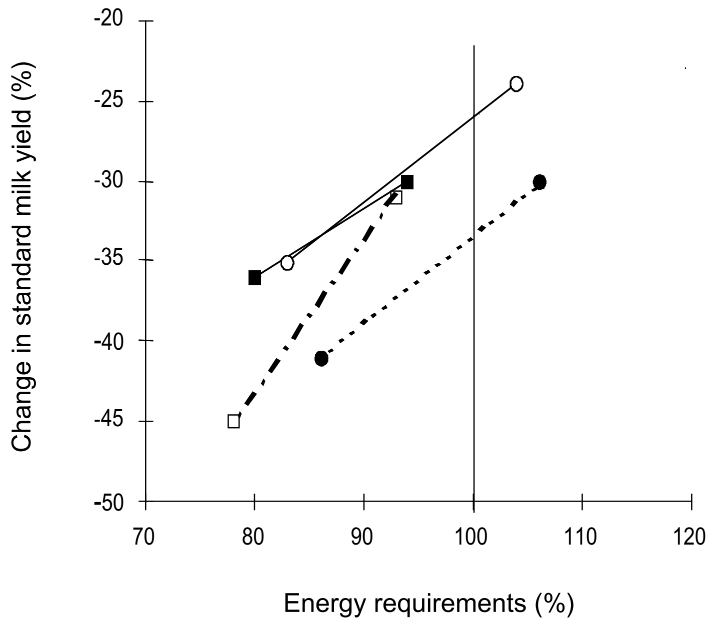

Fig. 1. Monthly decline of milk yield in Lacaune dairy sheep according to the covering degree of energy requirements (at maintenance or undernurrished) and stage of lactation in milking (Period 1: month 1; Period 2: month 2) from Bocquier *et al*. (1997a); , Experiment 1-Period 1; , Experiment 1-Period 2; , Experiment 2-Period 1; , Experiment 2-Period 2).

Effects of the level of dietary protein

The relationship between protein intake and milk production has been extensively reported in bibliography in both sheep (Robinson and Forbes, 1970; González *et al*., 1982, 1984; Treacher, 1983; Bocquier *et al*., 1987b), goat (Hadjipanayiotou, 1987; Morand-Fehr *et al*., 1991) and cow (Rémond, 1985; DePeters and Cant, 1992).

The main effects of level of dietary protein were summarized by Treacher (1983), from the model proposed by Robinson (1978), in the following manner: (i) at a particular level of energy intake there is a minimum protein intake, and reduction below this protein level will cause a reduction in milk yield; (ii) this minimum ratio of protein to energy increases with increasing level of milk yield; and (iii) an increase in dietary protein concentration without a change in energy intake will increase milk yield if the ewe has not reached her potential yield.

Analysis of ewes' references (Bocquier *et al.*, 1987b) indicate a quadratic relationship ($r^2 = 0.97$) between protein (PDI) supply over maintenance requirements and milk protein yield. Mean estimation of PDI efficiency was 0.56, which is close to the value (0.59) obtained by protein balances (Bocquier *et al*., 1987). Marginal increase of protein in milk as a result of protein intake was zero when intake was close to 300 gPDI/d. There was no significant effect of protein (PDI) balance on milk content of fat nor protein in the data reviewed by Bocquier and Caja (1993) in lactating sheep. Effects of dietary protein level on milk production of early lactating ewes are mainly attributed to energy savings as a consequence of an increase in body fat mobilization (Robinson *et al*., 1974, 1979; Cowan *et al*., 1981) and utilization (Geenty and Sykes, 1986).

Effects of the interaction of protein and energy levels in the diet of dairy ewes were studied by Cannas *et al*. (1998) in Sarda dairy ewes during mid-milking period and related to milk urea nitrogen. Ewes were fed in pens with whole pelleted diets varying in two energy and four protein levels. Results are summarized in Table 3.

Milk yield tended to increase and milk true protein to decrease with dietary protein level, in accordance with previous conclusions. Milk yield seems to reach a plateau above 19% of crude protein in the diet. Furthermore, the high energy level significantly reduced both milk yield and milk fat. Milk fat values were low and close to those observed in low fat syndrome, probably as a consequence of pelleted diets and of high content in non structural carbohydrates. True milk protein decreased with dietary protein level but was higher with the high, compared to the low energy diet.

Both milk urea and blood urea nitrogen were positively correlated with protein in the diet. Urea in these biological fluids was better related to protein concentration of the diet (r^2 = 0.82) than with protein intake (r^2 = 0.56) giving an effective indicator of N utilization. Milk urea of these ewes varied between 12-27 mg/dl according to protein level, which was lower than that measured in cow, and was neither affected by a.m. and p.m. milkings nor by the level of energy. The authors stressed the fact that high values (>16 mg/dl) are associated to high embryo losses in sheep, as obtained in this study with 16 or higher crude protein in milking ewes in mid-lactation.

Table 3. Effects of energy and protein content in the diet on milk yield and milk composition in dairy ewes (Cannas *et al*., 1998)

Item	Energy† level	Crude protein (% DM)				Mean
		14	16	19	21	
Milk yield (l/d)	L	1.26	1.43	1.50	1.48	1.42
	H	1.16	1.20	1.34	1.34	1.26
Milk fat (g/l)	L	60	57	57	59	58
	H	57	57	54	56	56
Milk true protein (g/l)	L	55	54	53	52	54
	H	57	54	53	54	55
Milk urea N (mg/dl)	L	12.9	17.7	23.4	26.7	19.9
	H	12.2	17.0	22.3	25.8	19.3

†L = 1.55 Mcal EN_L/kg DM (0.91 UFL/kg DM); H = 1.65 Mcal EN_L/kg DM (0.97 UFL/kg DM).

In addition, existence of significant correlation between same milk components in successive controls [fat: r = +0.5; protein: r = +0.7 (Barillet and Boichard, 1987)] suggests that effects of nutrition at early stage of lactation may have carry-over effects on milk composition during the milking period. Direct evidence of such effects are, however, lacking.

Effects of the level or proportion of concentrate

Effect of concentrate is positively associated to the energy level of the diet as a result of its high ingestibility and energy density, and as a consequence milk fat may be depressed and milk protein increased. Furthermore, the use of a high proportion of concentrates in diets (>60% of dry matter) may depress, by itself, both the milk fat and protein contents during the first months of lactation (Eyal and Folman, 1978). These effects being higher for Awassi (fat: –28 g/l; protein: –2 g/l) than for Assaf ewes (fat: –6 g/l; protein: +1 g/l) showing a breed difference in the response to concentrates.

Negative effects of concentrates on milk production are attributed to a quick and phasic degradation of non-structural carbohydrates in the rumen, reducing dramatically the rumen pH and altering the amount and composition of microbial protein synthesis and limiting the degradation of structural carbohydrates. These adverse effects of excess concentrate may be partially reversed by the use of pH buffers (Hadjipanayiotou, 1988). It is generally observed in group-fed ewes that the level of concentrate, if moderate, mainly affects the weight and body condition in lactating ewes, whereas bulk milk yield and composition are small or not significantly affected (Marín *et al*., 1996).

Effects of group feeding strategies

The dairy sheep allowances are established for an individual ewe or a group of ewes with similar performances and they do not take into account differences between animals, i.e., variability within the group of ewes to be fed (Bocquier and Caja, 1993; Bocquier *et al*., 1995). If possible, ewes should be allocated into homogeneous groups according to their characteristics (physiological status, prolificacy, stage of lactation, milk yield or suckling litter size and body condition score). However, when this allocation is not possible and ewes' performances are widely spread, it is a usual practice to supply more feed than the average recommended allowances of the group. In Lacaune dairy ewes for instance, the main aim of feeding strategies is to give a diet that is adequate for ewes that make the most important contribution to total milk production. These ewes produce about 10% more milk than the flock average.

Therefore, the energy supply for such a group of ewes is calculated for an individual milk production that is 10% above the actual mean milk yield. The protein supply is generally calculated for a milk production that is 30% over the mean milk yield. This is because of marginal responses both in milk yield and in protein content, although the excess of dietary protein induces a wastage of protein, especially for the low producing ewes of the group.

Few comparative trials of group-feeding strategies have been carried out in dairy ewes. An experiment was thus conducted (Bocquier *et al*., 1995) to compare the effect of two strategies of group-feeding. With this aim two similar groups of Lacaune dairy sheep (96 ewes each) were either fed altogether (all levels of milk yield confounded) or after separation in two subgroups according to milk yield (high and low). Total milk yield and milk composition were identical in both groups, but the "low-milk yield" subgroup showed a higher increase in body weight and body condition score at the end of the experiment. Most of the beneficial effects of group feeding are obtained on the saving of concentrates, with dairy performances generally maintained or only slightly improved.

On the other hand, at a given time, the main factor of milk yield variability in a flock comes from lambing dispersion, and direct effects of feeding on milk composition are hidden by the heterogeneity of performance. Studies have been conducted recently in France (Roquefort and Pyrenees) to measure the impact of within flock lambing kinetic on annual milk production and milk composition.

Effects of fat supplements

The importance of fat supplements in the diets of sheep has increased in the recent years as a result of the availability of fat as food and of favorable results obtained in dairy goats (Morand-Fehr *et al*., 1991) and cows (Palmquist and Jenkins, 1980). Nevertheless, available information is limited and is specially focused on the use of calcium soaps of long chain fatty acids (CSFA). The effect of protected fat on ewe milk production and composition has been reviewed by Casals and Caja (1993), Chilliard and Bocquier (1993) and Gargouri (1997). Main results during the milking period of dairy sheep are summarized in Table 4.

First experiments in suckling ewes (Pérez Hernández *et al*., 1986; Horton *et al*., 1992) tried to improve lamb growth with contradictory results, but the clearest response was obtained in the improvement of milk fat content in dairy ewes. Lactational (suckling and milking periods) effects of CSFA included in the concentrate fed to Manchega dairy ewes grazing in semi-intensive conditions have been reported mainly by Casals *et al*. (1989, 1991, 1992[a],b, 1999), Cuartero *et al*. (1992), Gargouri *et al*. (1995), Pérez Alba *et al*. (1997) and Osuna *et al*. (1998), these authors compared the use of oilseeds vs CSFA and Lacaune vs Manchega dairy ewes in indoors conditions. Although total milk yield was unaffected in all experiments, dietary CSFA significantly increased the milk contents of fat and solids, in most cases, and decreased slightly milk protein content in overall lactation. Responses varied according to CSFA dose and lactation stage.

Apparent efficiency of CSFA transfer to milk was higher in suckling than in milking ewes, and optimum intakes of CSFA per ewe to maximize milk fat production were close to 120 and 70 g/d, in suckling and milking periods respectively. The depressive effect of CSFA on milk protein increased with time after lambing, and optimum intakes of CSFA that maximized milk protein production were the same as for milk fat. Milk casein also decreased with CSFA, but casein content as a percentage of milk protein was unchanged in all cases in these experiments.

Fatty acids profiles in milk and cheese were changed with a strong increase in palmitic (C16:0) and oleic (C18:1) acids and a decrease in the C6 to C14 acids (Gargouri *et al*., 1997; Pérez Alba *et al*., 1997; Font *et al*., unpublished), but differences in fatty acids profile were not significant after the ripening of cheeses. Change in fatty acids profile of milk was dependent on CSFA profile (Gargouri *et al.,* 1995; Pérez Alba *et al*., 1997). Special care must be taken in relation to changes in lipolysis rate or organoleptic characteristics after modification of fatty acid composition in cheese.

Table 4. Effects of calcium soap of long chain fatty acids on milk production of Manchega dairy sheep during milking

Lactation period and reference	Basal diet	Lipid (g/d)	Yield (%)	Fat (g/l)	Protein (g/l)
Casals *et al*. (1987, 1992b, 1999)	Grazing	0	0.75	79	62
	Grazing	160†	0.78	97	56
	Grazing + protein supplement	0	0.73	85	64
	Grazing + protein supplement	160†	0.69	100	59
Casals *et al*. (1991, 1992a)	Grazing	0	0.74	74	60
	Grazing	40†	0.83	82	59
	Grazing	80†	0.70	94	60
	Grazing	120†	0.74	89	55
	Grazing	160†	0.71	94	56
Font *et al*. (unpublished)	Grazing	0	0.51	99	65
	Grazing	72†	0.53	105	61
Cuartero *et al*. (1992)	Grazing	0	0.45	92	–
	Grazing	75†	0.46	104	–
Gargouri *et al*. (1995)	Grazing	0††	0.94	82	67
	Grazing	72†, ††	1.00	84	63
Gargouri (1997)	Grazing	0	0.92	74	63
	Grazing	96†	0.83	83	61
Pérez Alba *et al.* (1997)	Oat-vetch hay	0	1.40	65	51
	Oat-vetch hay	166†††	1.56	68	49

†Calcium soaps of palm oil.
††Including 2% of animal fat and 3% of whole soybean seed in both concentrates.
†††Calcium soaps of olive oil.

More recently Osuna *et al*. (1998) studied the effects of feeding whole oilseeds, to partially replace CSFA, on dairy ewes intake and milk production and composition. In this aim Manchega and Lacaune dairy ewes were used in mid-milking period to determine the lactational effects of supplementing diets with fat coming from palm oil CSFA (5.5%) or from a mixture of CSFA (2.5%) and whole cottonseed (11%) or CSFA (2.5%) and whole sunflower seeds (4%). Diets were isonitrogenous (16% CP) and were offered as a total mixed ration (71% forage: 29% concentrate) where fat supplements were included. Ether extract increased from 2.5% in control to 7% in fat supplemented. Results are summarized in Table 5.

Due to the dietary fat, intake tended to decrease, while milk fat percentage and yield increased, and casein content was reduced. Milk yield was not affected by treatments in accordance with previous results. No interactions were found between breed and fat supplementation, in spite of the respective differences ($P < 0.01$) between Manchega and Lacaune dairy ewes in milk yield (0.9 and 1.7 l/d), and fat (89 and 73 g/l) and protein (62 and 56 g/l) contents, respectively. A significant effect ($P < 0.01$) was detected on milk casein as a percentage of total protein that decreased in response to lipid supplementation.

Table 5. Effects of feeding whole oilseeds and Calcium soaps of fatty acids on milk production and composition of Manchega and Lacaune dairy ewes during mid milking period (Osuna *et al*., 1998)

Item	Breed†	Control	CSFA††	CSFA + WCS†††	CSFA + SFS††††
Milk yield (l/d)	M	0.8	0.8	1.0	0.8
	L	1.7	1.7	1.5	1.7
Milk fat (g/l)	M	74	95	95	90
	L	61	77	82	70
Milk protein (g/l)	M	63	60	64	62
	L	55	55	58	55

†M = Manchega, L = Lacaune.
††CSFA = Ca soaps of fatty acids.
†††WCS = Whole cotton seed.
††††SFS = Sunflower seed.

Effects of protein supplements

Studies on the use of low degradable protein supplements, protected proteins or protected amino acids in milk production of sheep are very limited and most of the references were made using suckling ewes, altering the practical significance of data of milk composition in consequence.

In addition, in some cases the results are not significant or contradictory. With regard to low degradability protein supplements Robinson *et al*. (1979), Cowan *et al*. (1981), Penning and Treacher (1981), González *et al*. (1982), Hadjipanayiotou (1988), Penning *et al*. (1988), and most recently Purroy and Jaime (1995), showed increases in milk yield during early lactation when a degradable protein source was substituted by fishmeal (60-140 g/d) in lactating ewes.

Milk composition was, however unchanged in most cases and only significantly improved in the trials of Penning *et al*. (1988) and Purroy and Jaime (1995), when comparing soybean and fishmeal in suckling ewes. These last authors reported significant increases in milk protein (+2.9 g/l, +6.2%) but not in milk yield, probably as a consequence of the undernutrition (70-80% of energy requirements) applied in the experiment. Robinson *et al*. (1979) also found a slight increase ($P < 0.10$) in milk protein in ewes fed fishmeal, when compared with those fed soybean or peanuts protein supplements. Effects of fishmeal are attributed to an increase in the amount and profile of amino acids absorbed in the small intestine and that can be used by the udder for milk synthesis.

Use of protected proteins for milk production in dairy sheep gave also gave interesting results but in some cases were not significant or contradictory. Treatment of protein supplements with formaldehyde at optimum doses (Caja *et al*., 1977) is one of the recommended procedures in practice. In this sense, comparison of the use of soybean, fishmeal and formaldehyde protected soybean in Chios dairy ewes was without significant effects on milk yield and milk composition (Hadjipanayiotou, 1992), even if milk fat and milk protein contents were slightly higher in ewes fed formaldehyde treated soybean. The use of formaldehyde protected soybean in Chios dairy ewes in negative energy balance did not affect milk yield and composition either (Hadjipanayiotou and Photiou, 1995).

Industrially protected soybean by means of Lignosulphonate treatment is nowadays available for ruminants. Evaluation of treated vs untreated soybean was carried out in Manchega dairy ewes fed with poor quality forage at two levels of supplementation with concentrate (Pérez-Oguez *et al*., 1994, 1995). Values of effective degradability measured *in sacco* for treated and untreated soybean used in the experiment were 0.30 and 0.56, respectively. Obtained results are summarised in Table 6.

Differences between treatments were not significant, but a significant interaction ($P < 0.05$) was observed in the milk yield comparisons between the level of concentrate and degradability of protein. The highest values in milk yield were obtained with the high level of low degradability protein supplement soybean. Milk composition was unaffected by treatments.

More recently, protected amino acids have been used in lactating ewes to increase milk production during suckling (Lynch *et al*., 1991; Baldwin *et al*., 1993) or milking periods (Bocquier *et al*., 1994). Lynch *et al.* (1991) studied the supplementation with Methionine (0.11%) and Lysine (0.28%) of two concentrates for suckling ewes varying in its level of protein (10 and 16% crude protein).

The results obtained indicated a higher milk yield (+11%) in the ewes fed with the high protein supplemented concentrate, but the difference was not significant. Milk protein was also unaffected by both experimental treatments. The inclusion of protected Methionine (0.2%) in the concentrate produced small (+2%) and not significant increases in milk yield and milk protein as observed by Baldwin *et al.* (1993) in suckling Dorset ewes.

It has been also shown that the milk protein content of milk can be increased by the addition of 3 or 6 g/d of protected Methionine at the start of milking period in Lacaune dairy ewes (Bocquier *et al*., 1994). Ewes were in positive nutrient balance (117-120% and 120-140% of energy and protein requirements, respectively). The response to Methionine was higher when basal diet was based in silage than in hay, indicating that Methionine content could be the limiting amino acid in this last diet. Milk yield and milk fat content were unaffected by the supplementation.

Table 6. Effects of protected protein and level of concentrate on the milk production of dairy ewes during suckling and milking periods (Pérez-Oguez *et al*., 1994, 1995)

Item	Untreated soybean		Treated soybean	
	High†	Low††	High	Low
Milk yield (l/d)				
Suckling	1.45	1.42	1.61	1.26
Milking	0.59[ab]	0.58[ab]	0.70[a]	0.52[b]
Standard milk (l/d)				
Suckling	1.48	1.48	1.64	1.36
Milking	0.71[ab]	0.67[ab]	0.79[a]	0.59[b]
Milk fat (g/l)				
Suckling	84	88	84	91
Milking	58	57	57	59
Milk protein				
Suckling	49	49	49	51
Milking	58	57	57	59
Casein (g/l)				
Suckling	37	37	37	38
Milking	43	42	42	43

†Concentrate: 0.8 kg/d.
††Concentrate: 0.6 kg/d.
[a,b]Different letters in same line indicate significant differences at $P < 0.05$.

Conclusions

Manipulation of dairy sheep milk composition is of great importance when considering its final transformation into cheese. Overall, it must be kept in mind that the bulk milk used for cheese making comes from the whole flock production. Within this flock, lactating ewes are submitted to individual and collective constraints which interact during the course of lactation.

The main aim of the dairy sheep's nutrition is to sustain a high yield of milk and feeds are generally choiced in practice according to this aim. Nevertheless attention should be put in changes of milk constituents (total solids, protein, fat, casein, etc.). Results obtained in dairy cattle and goat may not be successfully extrapolated to dairy sheep. In addition, as dairy ewes are mostly bred in large flocks, it is also necessary to take into account the effect of flock structure on the composition of bulk milk.

The present knowledge on the main effects of nutrition on milk yield and fat and protein content of sheep milk has been reviewed in this paper, but it would also be necessary to take into account the effects of nutrition on minerals, trace elements and vitamins. Special attention should be paid to all factors that alter milk technological properties.

Finally, it should be stressed that the feeding of dairy ewes must ensure a healthy animal that gives a big amount of milk of high quality and health value which can then be used to produce the typical Mediterranean dairy products.

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