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EFFECT OF ENERGY SUPPLY ON MILK PRODUCTION AND MILK COMPOSITION OF DAIRY EWES

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ABSTRACT

During the cycle of reproduction, the lactating animal faced succesively of underfeeding and overfeeding. Two trials were done to evaluate the effect of energy supply on milk production and milk composition of dairy ewes. The first Trial (TI) was done to evaluate the effect of long term (2 months) underfeeding, while in the second trial (TII) mid-term (1 month) alternate effects of underfeeding and/or refeeding. Each trial was divided in two periods (P1 and P2) of one month (P1 : 28 days) and P2 (27 days). For each trial, mature Lacaune dairy ewes at mean lactation stages of 41 days (TI : n=18) and 48 days (TII : n=24) were allocated in one of two groups of feeding level (H: High or L : Low). Total Energy Requirement (TER) based on INRA recommendation (INRA, 1988) in TI was respectively for group H : 93 and 94% (P1 and P2) and for group L : 78 and 80%TER (P1 and P2), while in TII, animal in group H received 104 and 106 %TER (P1 and P2) compared to 83 and 86 %TER (P1 and P2) for group L. For both trials and for both groups, protein supply was 100% covered according to INRA recommendation. Ewes were machine milked twice a day at 8.30 am and 5.30 pm. Milk recordings were done twice a week on two successive morning and evening milkings. Milk samples were taken to be analysed for fat and protein content. Statistical analysis of all data collected was conducted with the GLM procedure of SAS (1988). Results of these trials indicated that energy supply directly altered milk yield. During the first period, between diet H and L, milk loss was of 20% in TI from initial milk yield of 2.46 liters/head/day and 17% in TII from initial milk yield of 2.16 liters/head/day. In the second periods respective differences were -31% (T1) and -14% (TII). Inversion of energy supply for the same animal (in the second period of TII) from L to H or from H to L altered significantly the evolution of milk yield. Overfeeding stimulate the better persistency. Effect of energy supply on milk fat and protein content was not significant among the groups. In conclusion, energy supply either for mid-term (1 month) or for long-term period (2 months) alter significantly milk yield evolution without significant effect on milk composition of lactating dairy ewes.

Key words : energy, milk yield, milk composition, dairy ewes.

INTRODUCTION

In large flocks of dairy ewes, even when feed supply is theoretically sufficient, competition for feed between animals often lead to underfeeding situations. This happen to the most productive ewes which have the highest requirements (Bocquier *et al.*, 1995). Another situation is frequently encountered in Mediterranean areas with feed restriction

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applied to the whole flock, due to large seasonal variations in feed availability (Sheath *et al.*, 1995). In suckling ewes, because of a slow evolution in feed intake (Bocquier *et al.*, 1987), it is frequent that ewes mobilise body reserves, during their short (few weeks) lactation (Cowan *et al.*, 1980, 1981). The losses of body mass are particularly important when ewes are in good body condition at lambing (Cowan *et al.*, 1982 ; Geenty and Sykes, 1986). Out of the early lactation period, which has been frequently studied in both in cattle and sheep, effects of undernutrition during the late part of lactation is not so well documented neither in cattle (Coulon and Rémond, 1991), nor in dairy ewes (Treacher, 1971 ; Bocquier *et al.*, 1985 ; Geenty and Sykes, 1986).

During full lactation of dairy ewes, for short term periods, it would be profitable to limit the adverse effect of underfeeding on milk yield by body reserves mobilisation (Bocquier *et al.*, 1990). Subsequently, the effects of refeeding on milk yield evolution is also of interest. Because this could be a part of feeding strategies based on alternate periods of under- and overfeeding. However, the extent of energy deficit that can be covered by body reserves mobilisation, and the duration of these periods of undernutrition are not known for dairy ewes. In vivo measurements of body energy and other terms of energy balance, allow calculation of efficiencies in the utilisation of energy by the lactating ewe. This point has recieve few attention on dairy ewes (Vermorel *et al.*, 1985). The aim of the present study was to evaluate the effect of energy shortage on the evolution of milk yield and its composition and to estimate the contribution of body reserves.

MATERIALS AND METHODS

Two separate trials were conducted to evaluate (Trial I) the effect of long term (2 months) underfeeding, while in the second trial (Trial II) mid-term (1 month) alternate effects of underfeeding and/or refeeding were studied. Each trial was divided in two periods (P1 and P2) of one month (P1 : 28 d) and P2 (27 d). The following code are used to identify groups of ewes : trial I (TI) ewes are kept on same diets during both period : HH and LL ; for the second trial (TII) diet were switched at the end of the first period : HL and LH.

For each trial, mature Lacaune dairy ewes (Trial I : n=18 ; Trial II : n=24) were allocated in one of two groups (feeding level High or Low), according to lactation stage, milk yield, body weight and age. The trials started with ewes at mean lactation stages of 41 d (TI) and 48 d (TII).

Milk control :Ewes were machine milked twice a day at 8.30 am and 5.30 pm. Milk recordings were done twice a week on two successive morning and evening milkings. Milk samples were taken to be analysed for fat (Gerber) and protein (Noir Amido). Milk yield (MY; l/d) had been transformed in standard milk yield (SMY ; l/d), taking into account the milk composition, with a formula established for dairy ewes (Bocquier *et al.*, 1993).

Feeding : Feeding objective was to maintain, for each ewe, a constant level of its energy requirements depending on the diet (High or Low) while protein supply was maintained above requirements (Bocquier *et al.*, 1987). In order to maintain the level of protein supply, while largely changing energy supply and controlling forage/concentrate ratio, numerous feeds where used in diets (hay, straw, dehydrated alfalfa, beet pulp, barley, rapeseed meal, meat meal and minerals (Table 1). The same natural pasture hay has been used during the two trials.

Offered feed was adjusted according to the individual milk yield and body weight (BW) : i.e feed supply was changed when milk yield, between two successive recordings, changed by more than 0.25 liter/d. Three steps of BW : BW<65 kg; 66 <BW < 74 ; BW >75

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kg were also used in diets calculations. For calculations of total energy requirements (TER) we used 397 kJ Metabolisable Energy (EM) /kg $BW^{0,75}$ for maintenance (INRA, 1988) and 5 MJ Net Energy for Lactation (NEL)/liter for the cost of one liter of standard milk (Bocquier et al., 1993). Protein requirement were expressed in the PDI system (INRA, 1988) cost of maintenance was assumed to be 2.5 g PDI /kg $BW^{0,75}$ and milk protein efficiency was estimated to be 0.58 (INRA, 1988). The ewes received their diets in two equals meals given after milkings, they had free access to water.

Feed offered and refused were controlled 4 days a week. Feed samples were weekly taken before being analysed (DM, OM, CP, NDF and ADF ; Table 1). For each trial, digestibility measurement were done on four diets. These diets were chosen to be representative of each period and for High and Low diets. Digestibilities were obtained by offering daily 1.7 kg DM of these diets to castrated wethers.

Photoperiod was kept constant by artificial illumination (16L:8D) and ambient temperature was maintained between 15 and 18 °C. Statistical analysis of all data collected was conducted with the GLM procedure of SAS (1988) using feeding level, trial and period as fixed effects, interactions between these factors were also examined. Pre-experimental measurements were used as covariates

RESULTS AND DISCUSSION

No health problems were encountered except for one ewe of trial II that left the experiment in the second period due to a severe mastitis.

Feed intake : Due to feed adjustments DM intakes followed the ewe's requirements : they decreased with milk yield. At the start of the experiment, total mean DM intake were not differents (ns) between trial : 2.29 (TI) and 2.18 (TII) kgDM/d and there was still no difference between trials at the end of experiment : resp. 1.54 et 1.47 kgDM/d. Overall mean differences of intake on the first period between groups High and Low were greater in TI : 0.51 kg than in TII : 0.25 kg DM/d, during the second period respective differences were 0.36 and 0.30 kgDM/d.

Table 1. Chemical composition and nutritive value of feed

	Chemical composition (%DM)				Nutritive value (/kg DM)	
Ingredients	OM	CP	ADF	NDF	UFL	PDI (g)
Hay	90.8	18.7	32.4	59.3	0.79	114
Barley straw	90.4	5.6	44.8	74.6	0.43	36
Dehydrated alfafa	89.4	19.6	33.3	44.5	0.70	110
Dehydrated pulpe of betterave	90.9	9.8	26.1	33.7	0.99	64
Barley	98.3	14.5	7.0	21.8	1.13	84
Rapeseed meal	92.4	39.0	21.3	36.1	0.88	252
Meat meal	65.4	-	-	-	0.52	390

UFL : Feed Unit for Lactation ; 1 UFL : 1700 kcal Net Energy for Lactation
PDI : Protein Digested in the Small Intestine
Mineral-mix was given 30 g/h/d.

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Nutritive values either for energy (1 UFL : 1.7 Kcal net energy for lactation; INRA, 1988) and protein (PDI : digestible protein at the level of intestine ; INRA, 1988) were calculated using equations and tables of INRA (1988). The whole dMO (from 0.66 to 0.70) and crude protein digestibilities (from 0.61 to 0.74) were taken into account for nutritive value of diets. These nutritives values of each component of diets (Table 1) were used to calculate individual energy and proteins supplied by diets.

Energy and protein supply : In trial I, ewes in High diet had their energy requirements nearly satisfied (P1 : 93% and P2 : 94% ; Table 2) while ewes in Low diet were largely underfed (P1 : 78% and P2 : 80 %). In trial II ewes in High group received more energy than needed (P1 : 104 % and P2 : 106%) and those in Low diet were less underfed in trial I than in trial II (resp. 83 et 86% TER for P1 and P2; Table 2). Between trials and diets differences were always significant ($P < 0.05$) during the first period : LL : 78 %, LH : 83 %, HH : 93% HL 104 %TER. During second period the two lower diets were not different (ns) while other were different ($P < 0.05$) ; LL : 80%, HL : 86%, HH : 94%, and LH 106%. Absolutes differences (UFL/d) were also significantly different ($P < 0.05$) either during the first period (LL : -0.39, LH : -0.29, HH -0.16 and HL : +0,07 or in second period except for the two lowest diets (LL : -0.26 and HL : -0.25) differences were significant (HH : -0,10, LH : +0,07). Protein supply were always sufficient both in Trial II (106 to 111% of requirements) and to a lesser extend in Trial I (99 % for LL diets). Due to the twice a week feed adjustment, the satisfaction of total energy requirements were stable, within group, during the time-course of the experiments (4%<CV<12%).

Adaptation of milk yield : Within trial, initial standardised milk yield (SMYi) were non-significantly different between feeding levels. However, between trial there was a difference ($P < 0.03$) of SMYi (Trial I : 2.46 l/d vs trial II : 2.16 l/d ; Table 2). This may due to an earlier mean lactation stage of ewes in trial I (41 d) compared to trial II (48 d). Probably due to the drop in the level of feed intake between the pre-experimental ad libitum feeding and the experimental controlled feeding, MY decreased in all treatments during the first week. The mean decline of MY was -0,35 l/d ; ewes in Low group continue to decline while High fed ewes had a stabilised MY. Energy supply directly altered milk output. In first part of experiment between diets High and Low milk loss was of 20 % in Trial I (9.9 liters) and 17 % in Trial II (7.3 liters). In the second periods respective differences were -31 % (11.0 liters) and -14 % (4.4 liters).

These difference come from evolutions of milk yield who directly depended on the level of energy supplied (Table 2). Hence, at the end of the first period (28d) milk yields were identical for HH and HL groups due to the fact that ewes that had the higest milk yield (HH : +0.30 l/d) recieved only 93 % of TER, while those having a lower milk yield (HL) were better fed (106% TER). The same evolution occured for ewes in Low diets. Initial difference of 0.32 l/d was abolished by the end of the first period (Trial I : 1.09 and Trial II : 1.06 l/d). The decline was more pronounced for LL (78%TER) than for LH (83% TER).

During the second period, ewe that were maintained at the same level of energy supply (Trial I) have had a linear decrease of milk yield. Differences between HH and LL groups were of 0.34 l/d at the end of 55 d. In Trial II, inversion of energy supply, altered the evolution of milk yield. By the end of the trial II, milk yield curves were very close (HL : 0.86 vs LH : 0.78 l/d). This is due to the rapid decline of MY for ewes that had been switched from 104 to 86 % and by a better persistency in ewes that were turned on from 83 to 106 % TER (Table 2).

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Altrough the physiological decline of milk yield, energy supply (%TER) of the ewe can altered the milk yield evolution. In order to compare the two trials (I and II) and the two periods (28 or 27d), we expressed the decline of milk yield (dSMY) relatively to initial milk yield (SMYi) by the relative decline ratio : dSMY%SMYi. In trial I, when ewes were slightly underfed (93 and 94 %), the mean relative decline is the same for the two periods (resp. -31 and -30 %). In first period, the decline in milk yield (-24 , - 31 and - 35%) is clearly dependent on %TER : resp. 104 , 93, 83 %. When the energy deficit was above 20 % of TER (i.e. 78 % TER), the decline dropped up to 45 % in 28d. For the same level of TER relative declines during trial II were always lower (-6.0 %) in the second period (-35.5 %) than in first period (-29,5 % ; see above).

In all situations where ewes were kept on the same diet, and above the threshold of 80 % TER there is a narrow relationship between relative milk yield decline (dSMY%SMYi) and the level of energy supply (%TER) :

$$dSMY\%SMYi = \underset{(\pm 0.004)}{0.490} \times \%TER - \underset{(\pm 0.7)}{75.9} \quad R^2=0.981 \quad n=5$$

One can calculate that when energy requirements are fulfilled (100%TER) the decline of milk yield is of 27 % in 28 days. Nevertheless, even if mean decline of milk yield is well linked to energy supply, individual relationship between these two parameters are not very clear. For a given mean level of energy supply (%TER), some of the ewes are able to maintain their milk yield while others exhibit a large decline in milk yield that allows to reduce their energy balance.

Despite the great variations in both milk yield and body weight at the start of trials the maintainement of energy and protein within a narrow range of requirement was successfully achieved. This choice was imposed by the use of the *in vivo* method of estimation of body composition. Because it was necessary to be sure that, for a given diet, ewe were kept on the same orientation of metabolism. For example, between two succesive estimations of body composition, underfed ewes were kept in negative calculated energy balance.

The higher relative decline in SMY during the second period of trail II may be due to the fact that ewes were switched abruptly to one level of feed supply to the other. In dairy cow, it has been showed (Moseley *et al.*, 1976) that such an abrupt decrease in energy intake is followed by a rapid decline in milk yield that persist for 3 wks. Inversely, increasing energy intake by mean of changing diet density lead to an increase in milk yield (Moseley et al., 1976).

There were few results (Vermorel *et al.*, 1985 ; Hadjipanayioutou and Photiou, 1995a) on the effect on milk yield of underfeeding in dairy ewes during full lactation period. During full lactation, most of available results on the effect of level of energy supply were obtained on cattle. For the present experiment, with mid-term undernutrition, the slope between mean values of milk energy decline and mean calculated energy balance of each group of ewes is 0.54 (±0.21 ; n=8 ; $P < 0.05$) i.e. the contribution of body energy to energy deficit is 46 %. Previous results on lactating dairy ewes estimated the contribution of body reserves to milk energy output was 46 % with dilution technique method and from 65 to 38 % with respiratory chambers measurements (Vermorel *et al.*, 1985).

Table 2. Energy supply, milk production and milk composition during two trials

Parameters	Trial 1		Trial 2	
	Low - Low (LL)	High - High (HH)	Low - High (LH)	High - Low (HL)
Energy supply (% Total req.)				
Period 1	78%	93%	83%	106%
Period 2	80%	94%	104%	86%
Protein supply (% Total req.)				
Period 1	98%	104%	106%	111%
Period 2	98%	104%	111%	106%
Standard milk production (l/d)				
Pre-trial	2.34 a	2.51 a	2.16 a	2.15 a
Early Period 1 (d1)	2.07 a	2.11 a	1.72 b	1.89 b
End Period 1 (d28)	1.11 bc	1.50 a	1.09 c	1.40 ab
End Period 2 (d55)	0.74 b	1.09 a	0.78 b	0.86 ab
Mean period 1	1.44 bc	1.81 a	1.33 c	1.60 ab
Mean period 2	0.86 b	1.25 a	0.93 b	1.09 ab
Milk fat composition (g/l)				
Pre-trial	65 a	65 a	64 a	68 a
Early Period 1 (d1)	64 a	63 a	65 a	69 a
End Period 1 (d28)	70 a	72 a	74 a	72 a
End Period 2 (d55)	83 a	80 a	79 a	86 a
Mean period 1	68 ab	66 b	70 a	68 ab
Mean period 2	80 a	75 a	76 a	78 a
Milk protein composition (g/l)				
Pre-trial	46 bc	45 c	51 a	50 ab
Early Period 1 (d1)	47 a	45 b	48 a	48 a
End Period 1 (d28)	53 a	52 a	52 a	49 a
End Period 2 (d55)	59 a	58 a	58 a	55 a
Mean period 1	50 a	48 b	50 a	48 ab
Mean period 2	57 a	53 a	54 a	53 a

Value followed by alphabet different (a, b, c) at the same row means different signicantly (P<0.05).

Compared to lactating cattle the ability of these ewes to sustain lactation by energy mobilisation is of same magnitude but seems to be more variable.

In refeeding situations, the switch form 83% to 106% of total energy requirements had a favourable effect on milk persistency. This results indicate, like in dairy cow (Windisch *et al.*, 1991), that transient energy deficit of few weeks can be partially restored when animals are realimented. In dairy ewes, compared to extrapollation previous evolution of milk yield under a 104 % TER, the milk increment was of 0.655 MJ/d on the whole period with a theoretical excess of energy of 1.68 MJ/d. Then the fraction of energy oriented toward milk yield represented 39 % of extra energy supply. Whindisch et al., (1991) discussed this point and observed that excess energy, 110 % above energy requirements, is necessary to restore milk production. This is necessary because body energy restoration, after a period of energy deprivation, takes priority over milk energy excretion.

The reasons for the variety of individual response of milk yield decline (dSMY%SMYi) to underfeeding (%TER) was unknown. In fact, during the first period, within diet there was a tendency ($P < 0.17$) for an opposite relationship between dSMY%SMYi and %TER : dSMY = -0.56 %TER with following constant terms according to the level of energy supplied : LL : -0.61 ; LH : -11.5 ; HH : -21.6 and HL : -34.1 %. The initial energy content of ewes (fatness), explained only partly ($P < 0.08$) differences among animals in their ability to sustain milk yield when underfed. The statistical model involved a

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quadratic term for body energy which means that the minimum milk loss was observed for ewes of medium energy content, while very fat (high energy content) and very lean (low energy content) ewes cannot maintain their milk yield when underfed. This does not agree with previous finding of Cowan et al., (1982) who founded that fattest ewes at lambing had the highest ability to loose body fat. Differences in the partition of energy between mammary gland and body reserves may be related to diffrences in both stage of lactation (early vs late) and milk extraction (suckling vs machine milking). This is why mid-lactating dairy ewes may differ strongly from early-lactating suckled ewes. Treacher (1971) showed that milk yield of milked ewes in early lactation was inversely related to body weight gain in pregnancy. This type of experiment may have altered the mammary gland secretory potential. However, when these ewes were fed ad libitum in lactation, the body-weight changes were in inverse order to the gains in preganancy (Treacher, 1971). This may also be due to a reduction of secretory tissue in the mammary glands. With restricted amounts of feed, the effect of level of body reserves on the ability to sustain milk yield is not known in mid-lactating dairy ewes.

Milk composition ; Despite differences in initial milk yield between trials, milk fat content were close and not different (TI : 65.1 vs TII : 65.6 g/l ; ns). Afterward milk fat content increased regularly as lactation stage progressed. At the end of the trials (+55 d) they were resp. 81.1 et 82.5 g/l . Effects of energy supply was only significant ($P < 0.02$) between highest (HH : 106 %TER) and lowest (LH : 78 %TER) with respective fat content of 65.7 and 69.9 g/l (Table 2). Even if differences were not significant during the second period, milk fat content of ewes in Low diet were higher than those in High diet.

Milk protein content were different ($P < 0.01$) before the trials started (TI : 45.6 and TII : 50.5 g/l ; Table 2), soon after trial started values became close (TI : 45.9 and TII : 46.5 g/l). Taking in account initial values of protein content by covariate analysis, revealed that none of the values were significantly affected by energy supply. On the other hand, differences in milk protein content that existed initially were kept significant ($P < 0.05$) between trials along the two periods (P1 : TI : 48.8 and TII : 49.3 g/l and P2 : TI : 55.7 and TII : 54.1 g/l).

Despite the initial variablity of the milk composition, it was possible to study the effect of energy supply, because covariates were highly significant ($0.0001 < P < 0.01$). Small or non-significants effects of energy supply on both fat and protein content were inconsitent with previoulsy observed effets of energy level in dairy cattle with a negative effect on fat content (-0.3 (g/kg)/UFL : Coulon and Rémond, 1991) and a positive effect for protein content (+0.5 (g/kg)/UFL : Rémond, 1985). The same tendancies were reviewed by Bocquier and Caja (1993) on suckled ewes. It was possible that differences between dairy species may come from the strong relationship between milk yield and its concentration of both fat (-6.48 (g/l)/l) and protein (-5.56 (g/l)/l ; Barillet and Boichard, 1987) in dairy ewes. This can explain the absence of effect of energy supply on protein ; there was a compensation between the increase of protein content due to the reduction of milk yield, and the decrease in protein content due to the negative relationship with energy balance. On the other side the small effect on fat content milk was not explained. Results of literature (Bocquier and Caja, 1993 ; Hadjipanayioutou and Photiou, 1995b ; Jaime and Purroy, 1995) had often be obtained in situation where both energy and protein energy balances were changed simultaneously. In our experiment the protein requirement were always satisfied.

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CONCLUSIONS

From the two trials, it can be concluded that energy level affected directly the milk secretion without significant effect on milk fat and milk protein content of lactating dairy ewes. The decline in milk yield was dependent on the percentage of TER. However, when the energy deficit was above 20 % of TER, the decline dropped up to 45 % of initial milk production. Inversion of energy supply for the same animal from L to H or from H to L altered significantly the evolution of milk yield. Overfeeding stimulated the better persistency. Energy supply either for mid-term (1 month) or for long-term period (2 months) altered significantly milk yield evolution.

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