

## **Relationship between nutrient intake, growth and body composition of the nursing foal**

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**Summary.** The milk and nutrient intakes of 21 nursing foals of heavy breeds (adult weight : 800 kg) were determined at 1, 4 and 8 weeks of age. Lactose intake increased ( $P < 0.01$ ) from 1 300 g/day at 1 week of age to 1 800 g/d at 8 weeks ; fat decreased ( $P < 0.01$ ) from 400 g/d to 300 g/d and protein did not vary (600 g/d). Energy and nitrogen intakes did not depend on the source of energy in the mother's diet.

Milk, energy and nitrogen intakes were well related ( $r = 0.74$  to  $0.81$ ) with foal growth between 1 and 4 weeks, but not between 4 and 8 weeks. The composition of weight gain showed a greater deposition of protein than of lipids until 8 weeks. Lipid and protein contents in empty body weight were 5.3 and 19.2 %, respectively, at 1 week and 9.0 and 19.9 % at 8 weeks.

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### **Introduction.**

During the first months of postnatal life, the foal eats only a few solid feeds (Martin-Rosset, Doreau and Cloix, 1978). Almost all the nutrients needed to meet maintenance and growth requirements come from the mare's milk. Preliminary studies on a few animals (Doreau, Martin-Rosset and Dubroeuq, 1982) have shown a weak relationship between milk intake and foal growth. This relationship is stronger in other species such as cattle (Le Neindre, 1974) or rabbits (Lebas, 1969).

In the present trial, we took into consideration milk composition and analyzed relationships between milk, energy and nitrogen intakes on the one hand, and foal liveweight gain and lipid and protein retention *in vivo* on the other.

### **Material and methods.**

*Animals and experimental diets.* — Twenty-one mare/foal pairs of heavy French breeds (Bretonne, Comtoise), weighing on an average 800 kg when adult, were studied during the first two months of nursing. In 1983 ten mares were divided

into two groups. Five mares received a diet *ad libitum* containing 95 % of tall fescue hay (2nd cut) and 5 % of a concentrate (93 % soybean meal) (group 1a) ; the other 5 received a diet containing 50 % of the same hay and 50 % of a concentrate (83 % barley and 12 % soybean meal) (group 1b). These diets provided sufficient amounts of nitrogen but differed as to the estimated amount of glucose in the end-products of digestion. During the same period in 1984, 11 mares received a diet containing 85 % of natural grassland hay (1st cut) and 15 % of a concentrate (50 % barley and 45 % soybean meal) (group 2). The main results on milk production and composition will be published elsewhere.

### Measurements

*Foal intake of milk and nutrients.* — Milk intake was determined by the dilution of deuterium oxide, as a marker of foal body water, according to Doreau and Dussap (1980) at 1, 4 and 8 weeks of lactation. A milk sample was taken during a milking representative of sucking as described by Doreau *et al.* (1986). Milk composition was determined by Gerber for fat, Kjeldahl for nitrogen, infrared spectrophotometry for lactose, atomic absorption spectrophotometry for calcium and colorimetry for phosphorus. Gross energy was measured by calorimetry (group 2) or estimated (groups 1a and 1b) by multiple regression from 27 samples of group 2, according to the following formula :

$$GE = 8.97 F + 5.25 N + 4.10 L \quad (r^2 = 0.995 ; S_{yx} = 6.0)$$

where GE is milk gross energy in kcal/kg and F, N and L are milk fat, nitrogen ( $N \times 6.38$ ) and lactose in g/kg, respectively.

Daily mean intakes of energy and nitrogen between weeks 1 and 4 (period 1) and between weeks 4 and 8 (period 2) were calculated by the arithmetical mean of the intake for each of the weeks limiting these periods.

*Foal growth and body composition.* — Foal liveweight was determined at 1, 4 and 8 weeks by double weighing at fixed times. Body composition (lipid, protein) was estimated from the water content of empty body weight, as in other species. It was assumed that, as in growing cattle (Robelin, 1982), body water volume was 3 % lower than deuterium oxide dilution space. Empty body weight and empty body water (EBWAT) were estimated assuming that digestive content was 3 % of the liveweight at 1 and 4 weeks and 4 % at 8 weeks (as in calves) and contained 88 % water. Lipid weight, calculated by the difference between empty body weight and the fat-free mass (FFM), was obtained with the equation :  $FFM = 1.161 EBWAT^{1.026}$ , established from slaughter data on light breed foals at birth (Meyer and Ahlswede, 1976) and at 4 months (Schryver *et al.*, 1974), taking into consideration the differences in maturity between heavy and light breeds for a same body weight. It was assumed that the body water/fat-free mass ratio was the same for the two types at the same maturity, Protein weight was estimated as 79 % of fat-free dry matter from bibliographical data on 4-month old foals.

From these estimates of body composition at 1, 4 and 8 weeks, we calculated the amount of lipids and proteins retained during periods 1 (weeks 1 to 4) and

2 (weeks 4 to 8). The energy retained was calculated assuming a gross energy value of 9.31 kcal/g for lipids and of 5.38 kcal/g for proteins (Robb *et al.*, 1972).

## Results.

**Foal nutrient intake.** — Nutrient intake (fig. 1) was 1 000 to 2 000 g of lactose, 500 to 700 g of protein and 200 to 500 g of fat daily. These data were submitted to variance analysis with two main factors (group, lactation stage), a hierarchical effect (animal) and a group/stage interaction. Lactose intake increased sharply ( $P < 0.01$ ) between 1 and 8 weeks while gross energy increased only between 1 and 4 weeks ( $P < 0.01$ ). Fat decreased ( $P < 0.01$ ) and crude protein was fed in rather constant quantities. The differences between groups were significant ( $P < 0.05$ ) for lactose, fat and gross energy intakes but not for protein intake. The daily intake of calcium and phosphorus did not differ between groups or stages; the mean values for each stage were 28.7, 29.8 and 26.7 g of Ca and 11.2, 11.7 and 10.6 g of P at weeks 1, 4 and 8, respectively. These different results must be related to a slight variation in daily milk intake between stages and groups (Doreau *et al.*, in progress); at weeks 1, 4 and 8 they were respectively  $18.9 \pm 1.8$ ,  $23.4 \pm 5.3$  and  $26.0 \pm 7.5$  kg for group 1a;  $21.0 \pm 2.0$ ,  $26.6 \pm 2.2$  and  $23.0 \pm 2.5$  kg for group 1b;  $21.7 \pm 1.1$ ,  $23.8 \pm 1.1$  and  $24.6 \pm 1.0$  kg for group 2. Nutrient intake per kg of metabolic weight decreased regularly; at 1, 4 and 8 weeks the means were 50.5, 41.7 and 35.5 g of lactose; 20.6, 14.4 and 11.5 g of protein; 15.4, 9.8 and 6.0 g of fat and 453, 339 and 250 kcal of gross energy.

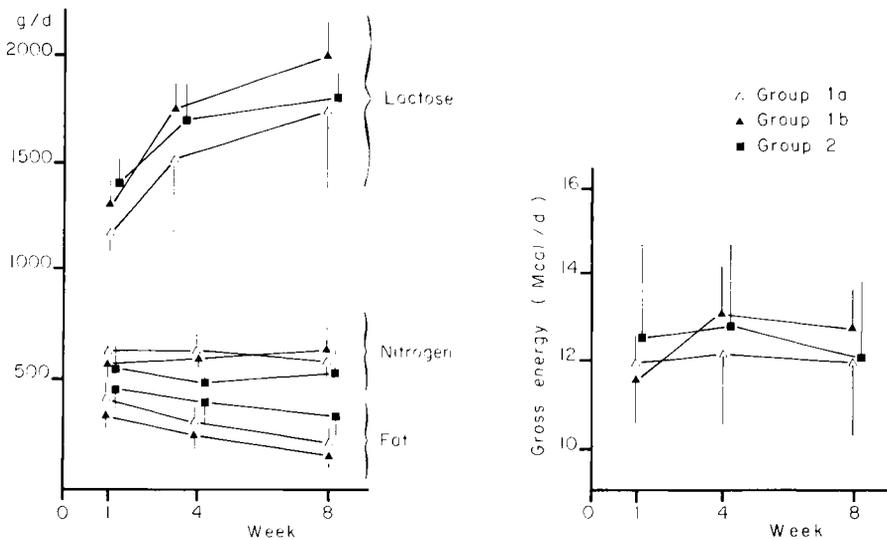


FIG. 1. — Quantity of foal nutrient intake (mean and standard deviation).

*Relationship between milk or nutrient intake and foal growth.* — The amounts of milk, gross energy and protein intake per kg of foal liveweight gain were  $10.6 \pm 0.9$  kg,  $5.8 \pm 0.5$  Mcal and  $258 \pm 27$  g, respectively, in period 1 and  $13.7 \pm 1.7$  kg,  $6.5 \pm 0.7$  Mcal and  $292 \pm 34$  g in period 2.

The linear correlation between milk intake and foal liveweight gain (fig. 2) was better in period 1 ( $r = 0.81$ ;  $n = 19$ ;  $P < 0.01$ ) than in period 2 ( $r = 0.74$ ;  $n = 18$ ;  $P < 0.01$ ). Liveweight gain was no longer related with gross energy intake ( $r = 0.78$  in period 1;  $r = 0.68$  in period 2) or protein intake ( $r = 0.74$  and  $0.61$  respectively). These relationships were all significant ( $P < 0.01$ ). The relationship between liveweight gain and milk or gross energy intake did not vary according to group. However, the relationship differed between groups 1a and 1b on one hand, and group 2 on the other, as to liveweight gain and nitrogen intake: the respective correlation coefficients were  $0.87$  ( $n = 10$ ;  $P < 0.01$ ) and  $0.84$  ( $n = 9$ ;  $P < 0.01$ ). There was no correlation between liveweight gain and the milk energy/protein ratio.

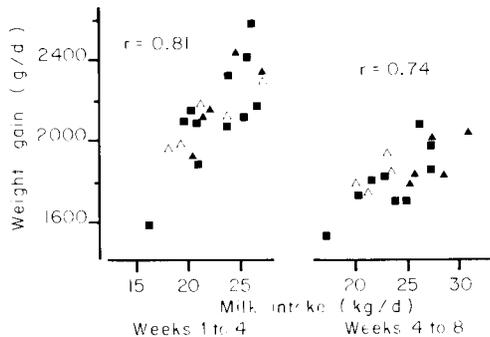


FIG. 2. — *Relationship between foal milk intake and foal liveweight gain* (mean and standard deviation).  $\triangle$  Group 1a;  $\blacktriangle$  Group 1b;  $\blacksquare$  Group 2.

*Foal body composition and nutrient retention.* — The proportion of EBWAT in the empty body weight of 21 foals was  $70.6 \pm 1.8$ ,  $69.1 \pm 1.9$  and  $66.2 \pm 1.7$  % at 1, 4 and 8 weeks, respectively. The equations of marker dilution used for this measurement were all adjusted with a correlation coefficient higher than 0.991. Body composition was estimated in 14 foals (table 1); we discarded 7 of these results, in which one of the three mean EBWAT/empty body weight ratios was 1.5 times higher than the standard deviation.

The percentage of lipid in empty body increased greatly between 1 and 8 weeks, whereas the percentage of protein remained rather constant. However, during this period, protein deposition (19.3 kg) was higher than lipid retention (11.3 kg). So, in period 1, the foals retained, per day,  $184 \pm 101$  g of fat,  $446 \pm 60$  g of protein and  $4.1 \pm 0.9$  Mcal of gross energy. In period 2, daily retention was  $265 \pm 80$  g,  $342 \pm 39$  g and  $4.3 \pm 0.8$  Mcal, respectively. The ratio of protein and lipid retained varied from 2.4 in period 1 to 1.3 in period 2.

TABLE 1

*Foal body composition* (mean and standard deviation).

	Foal age (in weeks)		
	1	4	8
Empty liveweight (kg) .....	79.2 ± 10.0	125.4 ± 12.7	173.0 ± 15.5
Empty body composition (%):			
water .....	70.3 ± 1.1	68.3 ± 1.5	66.6 ± 1.0
lipid .....	5.3 ± 1.2	6.5 ± 2.0	9.0 ± 1.5
protein .....	19.2 ± 0.2	19.9 ± 0.5	19.9 ± 0.4
Lipid weight (kg) .....	4.3 ± 1.5	8.2 ± 2.8	15.6 ± 3.0
Protein weight (kg) .....	15.2 ± 1.9	24.9 ± 2.7	34.5 ± 3.4

## Discussion.

*Foal nutrient intake.* — The intake levels of the different nutrients absorbed were independent of the mare's diet. As the milk composition is modified, the foal, as the calf (Le Neindre, 1974), probably adjusts its milk intake to fit nutrient requirements. The milk production of the mare fed *ad libitum* did not seem to limit foal growth. This hypothesis is supported by a low variation in nutrient intake between birth and 2 months as well as in requirements calculated from the theoretical growth curve (Martin-Rosset, Doreau and Espinasse, 1986).

Milk intake per kg of liveweight gain between 10 and 14 kg confirms results obtained by ourselves (Doreau, Martin-Rosset and Dubroeuq, 1982) or by Bouwman and Van der Schee (1978) and Oftedal, Hintz and Schryver (1983) with light breeds.

*Relationship between nutrient intake and foal growth.* — The relationship between foal liveweight gain and milk intake was closer in this trial than in a previous work (Doreau, Martin-Rosset and Dubroeuq, 1982), probably because there were more data and the calculation of liveweight gain over a longer period was more accurate. However, this relationship is weaker than that obtained by Salmon-Legagneur and Aumaitre (1962) in piglets or by Lebas (1969) in young rabbits. Perhaps these differences are related to methodological problems or feeding conditions since other authors studying piglets obtained a correlation of 0.58 (Lewis, Speer and Haught, 1978). These species differences might be due to the proportion of maintenance in the total requirements, which are higher and more variable in foals than in piglets or young rabbits.

The strength of the relationship decreases with foal age, probably because of the greater proportion of maintenance requirement and because of a possible intake of low amounts of forage after one month of age. It is surprising that this relationship is not higher when liveweight gain is related to energy or nitrogen intake. It may be that two milkings are not enough to precisely determine mean milk composition over a 3 or 4-week period.

In period 1, the relationship between protein intake and liveweight gain was very close within the same year of measurement. This could indicate that the

nitrogen supply, more than the energy supply, limited foal growth during this period, as suggested by the high protein retention/protein intake ratio. Such an observation was made in weaned foals eating a lysine-deficient diet (Breuer and Golden, 1971) and in reared lambs given an low-protein diet (Norton, Jagusch and Walker, 1970). These results are not found in nursing offspring ; milk generally equilibrates the nutrients, allowing optimal growth. Meadows *et al.* (1979) observed that a protein deficiency in the mare's diet caused a decrease in foal growth, but it is possible that the milk protein percentage does not vary when milk yield decreases, as in cows (Rémond, 1985), leading to limited supplies of energy and nitrogen at the same time.

*Foal body composition.* — The percentage of water in the foal body was close to that previously obtained by the same method (Doreau, Martin-Rosset and Agabriel, 1983) and consistent with most published data, particularly those of Schryver *et al.* (1974) and Meyer and Ahlswede (1976) on slaughtered animals only ; the *in vivo* values of Oftedal, Hintz and Schryver (1983) are considerably higher.

The calculated percentages of empty body lipid (nearly 6 % at week 1 and 9 % at 2 months) were higher than obtained in saddle breeds : 2.6 % at birth (Meyer and Ahlswede, 1976) and 5.3 % at 4 months (Schryver *et al.*, 1974). Heavy breed horses probably have more fat at the same age than saddle horses (Julian *et al.*, 1956). A methodological problem certainly remains to be solved, but it is difficult to evaluate the more reliable data. Estimated lipid percentages vary between 1.4 (Mendel, 1973) and 24 % (Julian *et al.*, 1956) of liveweight in adult horses. This variation is comparable to that observed in ovines and cattle (see review of Robelin and Thériez, 1981). An intermediate value of 10 % has been estimated for heavy breed foals at 6 months by Agabriel, Martin-Rosset and Robelin (1984).

Protein deposition is very high in the first months after birth. It is higher than lipid deposition at 2 months, at which time, this is not true in ruminants (Robelin and Thériez, 1981) or in swine (Whittemore, Aumaitre and Williams, 1978) at the same proportion of adult weight. This can be related to the low percentage of adipose tissue in horses as compared to that of other species (Martin-Rosset *et al.*, 1983).

## Conclusion.

Nursing foals have a very high growth rate, permitting body weight to double between birth and 2 months. This is due to a high nutrient intake. The nature of the carbohydrates in the mare's diet, when fed *ad libitum*, does not modify foal intake of energy or protein. However, different problems that remain to be studied are : the putative role of the protein supply in the mare's diet as a limiting factor of foal growth and its consequences on the composition of foal weight gain : more generally, the conditions in which the mare's milk yield limits foal growth.

**Résumé.** *Relation entre les nutriments ingérés et la croissance chez le poulain allaité.*

La consommation de lait et de nutriments par des poulains allaités de race lourde (poids adulte : 800 kg) a été déterminée à 1, 4 et 8 semaines sur 21 poulains.

La consommation de lactose s'est accrue ( $P < 0,01$ ) de 1 300 g/j à 1 semaine à 1 800 g/j à 8 semaines, la consommation de matières grasses a diminué ( $P < 0,01$ ) de 400 à 300 g/j et celle de protéines n'a pas varié (600 g/j).

Les quantités d'énergie et d'azote consommées n'ont pas dépendu de la nature des nutriments du régime de la mère.

Les consommations de lait, d'énergie et d'azote ont été bien reliées ( $r = 0,74$  à  $0,81$ ) à la croissance du poulain entre 1 et 4 semaines, et moins bien entre 4 et 8 semaines. La composition du gain de poids a montré un dépôt de protéines plus important que le dépôt de lipides jusqu'à 8 semaines. Les teneurs en lipides et protéines du poids vif vide étaient respectivement de 5,3 et 19,2 % à 1 semaine, 9,0 et 19,9 % à 8 semaines.

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