DOES A LOW QUALITY DIET IMPACT THE SUCCESS OF TWIN PREGNANCY AND THE CARCASS QUALITY OF MEAT PRODUCING LAMBS?

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Abstract – Perturbations of the prenatal and post-natal environments are known to have metabolic, physiological and behavioral impacts later in life. This study investigated the effects of low quality *versus* high quality diets without complementation from mid- to near-term gestation on growth capacities, metabolic profile and carcass quality of 5 month-old meat producing lambs. Between weeks 11 and 19 of pregnancy, multiparous Romane ewes were fed ad libitum either a high quality/low fiber hay (well-fed; covering 100% of energy and protein requirements; n = 15) or a low quality/high fiber hay (restricted; covering 50-70% of protein and energy requirements; n = 15). The underfed state of ewes fed the low quality hay was ascertained by the increased plasma level of non-esterified fatty acids and beta-hydroxybutyrate relative to well-fed ewes, while those of glucose, urea and amino acids decreased. The maternal dietary restriction did not impact pregnancy success or lambs' body weight at birth. No strong differences were recorded between lambs born from well-fed and restricted ewes in terms of morphometric, metabolic profile and growth or slaughter measurements. These results are of fundamental interest to the field of ruminants' adaptation to variability of their forage quality induced by climatic perturbations.

Key Words – fetal programming, low quality forages, lamb growth, metabolic features, carcass quality

I. INTRODUCTION

In low input ruminant breeding systems undergoing climatic perturbations, i.e. severe droughts, forage quality or availability may strongly vary, thereby affecting the nutritional status of ruminants. When periods of low forage quality occur concomitantly with gestation and/or lactation, the dam undergoes a series of metabolic and physiologic adaptations to ensure the supply of nutrients to the offspring.

Fetal and post-natal metabolic adaptations to maternal nutrition exist and impact post-natal life at least in sheep, as it is exemplified by the disproportionately higher rate of fat gain relative to muscle gain [1], or by the altered feeding behavior [2] observed in offspring born from mother restricted during pregnancy. The few results available to date (for review see [1]) suggest that the lean-to-fat ratio, a key determinant of carcass quality and meat production, is not adversely affected in the long term by growth *in utero*, and may be strongly determined by the feeding level succeeding the period of nutrient restriction, i.e. the end of pregnancy or the first post-natal weeks. Moreover, the post-natal consequences of maternal nutrition have been mainly addressed with diets that induce strong variations in nutrient supply either during pregnancy or post-natal life. In the present study our objectives were to explore the impact of feeding twin-bearing gestating ewes, during the second half of gestation, with a low quality diet (that mimics foraging conditions experienced by non-complemented ruminants in low input breeding systems undergoing climatic perturbations) on their ability to carry pregnancy to term, and on their lambs' growth capacities and carcass quality.

II. MATERIALS AND METHODS

Twin-pregnant multiparous dry Romane ewes were identified among available animals by ultrasonography. At week 11 (W11) of pregnancy, ewes were allotted to one of two nutritional groups: Restricted (R, n = 15) or

Well-fed (WF, n=15). At lambing, the number of ewes in each group decreased to n=10 (R) and 9 (WF) due to errors of twin pregnancies diagnostic and to lambs mortality.

Restricted ewes were fed *ad libitum* a low quality/high fiber permanent pasture hay (first late cut, Net energy = 1.07 Mcal/kg DM, Metabolizable protein = 71 g/kg DM, with a shortage in rumen degradable N) expected to cover until week 19 (W19) of pregnancy about 50 % of protein (MP) and 70 % energy (NE) recommendations for maintenance and gestation (INRA, 2007). Well-fed ewes were fed *ad libitum* a high quality/low fiber permanent pasture regrowth hay (Net energy = 1.55 Mcal/kg DM, Metabolizable protein = 100 g/kg DM, with an adequate supply in ruminal degradable N) expected to cover 100% of the energy and protein requirements for maintenance and gestation. From W19 of pregnancy to weaning (11 weeks after lambing) all ewes were fed the high quality hay, complemented with restricted amounts of barley and soya bean meal from W4 to W9 of lactation). Ewes had free access to fresh water at all times.

Throughout the experiment, measurements in ewes consisted in recording weekly body weight and body condition score (BCS), and in collecting monthly blood samples from the jugular vein before meals. The twin-lambs were milk-fed by their mothers during 11 weeks, firstly exclusively on the first 5 weeks then complemented until weaning with restricted amounts of the regrowth hay and concentrate for lamb growth that aimed to cover a maximum of 40% of maintenance requirements (INRA, 2007). At weaning, only male lambs were kept for the rest of the experiment to avoid potential sex differences in treatments effects. All lambs (10 from R ewes and 9 from WF ewes) were fed *ad libitum* the high quality hay complemented with restricted amounts of concentrate for lamb growth so as to supply a maximum of 40 % of maintenance requirement until slaughter. Lambs were weighted weekly and blood samples were collected monthly. Lambs were slaughtered at a targeted body weight of 40 kg (about 5 months of age). Blood samples were used for the determination of plasma levels of glucose, acetate, Non-Esterified Fatty Acids (NEFA), and beta-hydroxybutyrate (BHBA) with an Arena 20XT (Thermo Scientific, Vaanta, Finland) automated analyser by spectrophotometric enzymatic assays using specific kits (981820 kit for urea, 981379 kit for glucose, 984325 kit for BHBA from Thermo Scientific and W1W434-91795 kit for NEFA from WAKO Unipath). Plasma amino acid concentration was determined by spectrophotometric analysis of α-amino group as described by Satake et al. (1960). At slaughter, the body, carcass, organs and major tissues were weighted.

Differences between the two nutritional treatments at one time-point were tested using Student's unpaired t-test with differences considered significant at $p < 0.05$.

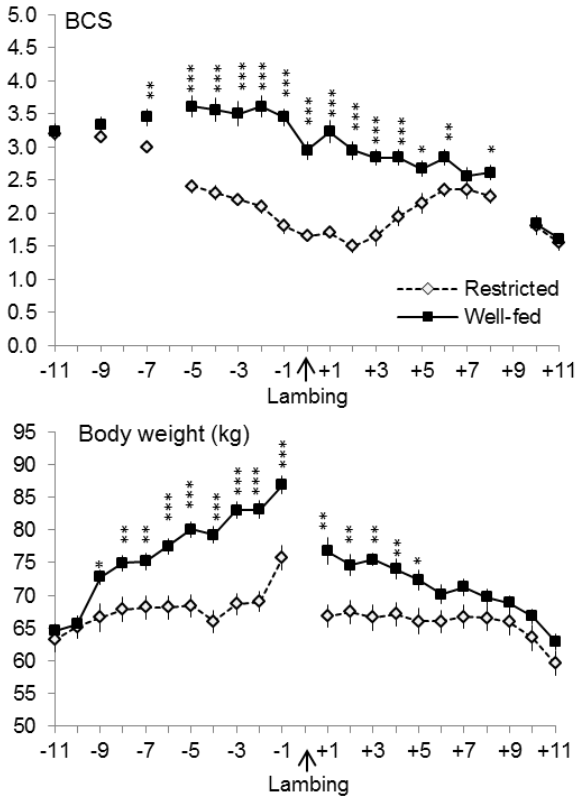

Figure 1. Body condition score (BCS) and body weight of restricted and well-fed ewes. The diet was different between groups from weeks 11 to 19 of gestation (so from week -11 to -3 relative to lambing). Data are mean ± SE, * P <0.05, ** P<0.01, *** P<0.0001.

III. RESULTS AND DISCUSSION

Gestation length was similar for WF and R ewes (145.6 ± 1.4 d, P = 0.24). Body condition scores

(BCS) were initially similar between treatments but became lower in R ewes from W7 before lambing until W6 after lambing, after which both groups showed similar scores up to the end of the experiment (Fig. 1). As for BCS, body weights were initially similar then significantly differed between groups from W9 before lambing, mainly due to a great increase in WF ewes compared to a stagnation in R ones. Finally, it was not until W8 after lambing that body weights returned similar between groups.

Restricted ewes showed greater BCS loss and lower body weight gain during pregnancy compared to WF ewes, suggesting a higher mobilization of body stores, mainly from adipose tissue mass. This was confirmed by an increase in plasma concentration of NEFA, arising from fat mobilization, and of BHBA, probably reflecting an increased hepatic ketogenesis from mobilized NEFA, in R compared to WF ewes at the end of the restriction period (W19, Table 1).

Table 1. Plasma concentration of metabolites in well fed (WF) and restricted (R) pregnant ewes and their offspring at different times throughout the experiment

		NEFA (mmol/L)	BHBA (mmol/L)	Glucose (g/L)	Urea (g/L)	Amino acids (mmol N/L)
Ewes W11 gestation	WF	0.762 (0.112)	0.369 (0.040)	0.394 (0.036)	0.473 (0.024)	2.63 (0.087)
	R	0.805 (0.080)	0.427 (0.012)	0.477 (0.034)	0.479 (0.036)	2.46 (0.063)
Ewes W19 gestation	WF	0.205^{b} (0.033)	0.368^{b} (0.025)	0.463^{b} (0.013)	0.437^{b} (0.020)	2.94^{b} (0.090)
	R	0.708^{a} (0.10)	0.601^{a} (0.093)	0.375^{a} (0.017)	0.150^{a} (0.011)	1.95^{a} (0.085)
Ewes Lambing	WF	0.275^{b}(0.031)	0.400 (0.024)	0.501 (0.017)	0.399 (0.025)	3.12 (0.133)
	R	0.166^{a} (0.036)	0.427 (0.031)	0.540 (0.020)	0.424 (0.022)	3.04 (0.134)
Ewes W4 lactation	WF	0.458 (0.076)	0.590^{b} (0.049)	0.591 (0.025)	0.546 (0.020)	2.60 (0.168)
	R	0.289 (0.130)	0.427^{a} (0.027)	0.548 (0.037)	0.541 (0.025)	2.89 (0.167)
Lambs 1 month-old	WF	0.135 (0.013)	0.176 (0.020)	0.736 (0.071)	0.321 (0.015)	2.86 (0.088)
	R	0.105 (0.008)	0.190 (0.012)	0.767 (0.042)	0.351 (0.023)	2.60 (0.153)
Lambs 5 month-old	WF	0.189 (0.049)	0.297 (0.020)	0.674 (0.033)	0.311 (0.029)	1.81 (0.089)
	R	0.138 (0.029)	0.320 (0.019)	0.737 (0.046)	0.313 (0.035)	1.97 (0.067)

Values are means (± SE). For a metabolite within two consecutive lines, different superscripts indicate a difference between restricted and well-fed groups (P <0.05). NEFA: non-esterified fatty acids; BHBA: beta-hydroxybutyrate.

Conversely, concentrations of glucose, urea and amino acids were lower in R ewes, in agreement with the expected energy and protein restriction induced by the low quality diet (Table 1).

At birth, the average weights of male lambs were similar between those born from R (4.03 ± 0.49 kg) or WF ewes (4.30 ± 0.59 kg) (P = 0.3). When comparisons were made for morphometric or growth measurements, some trends for differences between lambs were observed. The weight just before weaning (20.5 ± 2.0 *vs* 24.0 ± 3.2 kg, P = 0.016) was lower in lambs born from R than from WF ewes, maybe due to a lower milk production as milk quality appeared not affected. However overall, the average daily gain (ADG) from birth to slaughter (219 ± 6 g/day in R *vs* 230 ± 8 g/day in WF lambs, P = 0.3) as well as the number of days of growth required from birth to reach the targeted 40-kg body weight (163 ± 4 d in R *vs* 154 ± 4 d in WF lambs, P = 0.12) were close between groups. In agreement with our results, a lack of difference was reported for birth weight and total weight gain between birth and 4 months [3] or 1 year of age [4], in lambs born from mothers restricted (50 % of requirements) during early (28-78 days, [3]) or late (110 days-term, [4]) gestation.

When comparison was made for metabolic feature of lambs, no differences in plasma concentration of NEFA, BHBA, glucose, urea and amino acids were observed between lambs born from WF or R ewes at either one or five months of age (Table 1). This is in agreement with the lack of difference of glucose and NEFA plasma concentrations reported in 1 year-old fasted sheep born from mothers restricted *vs* well-fed during late gestation [4].

At slaughter, no differences were observed between lambs born from R *vs* WF ewes for carcass weight, subcutaneous back fat thickness (Table 2), nor for relative weights (reported to hot carcass weight) of skin, adrenals, testis, full and

empty components of the digestive tract, and perirenal and mesenteric adipose tissues.
However, the relative weights of liver, heart and kidney, very metabolically active organs, were about 10% higher in lambs born from R than from WF ewes (Table 2).

Table 2. Carcass characteristics of lambs born form restricted (R) or well-fed (WF) ewes

	R	WF	p-value
Live weight at slaughter (kg)	39.5 (0.45)	39.3 (0.69)	0.752
Hot carcass weight (kg)	17.20 (0.30)	17.46 (0.44)	0.642
Subcutaneous back fat thickness (mm)	2.80 (0.20)	2.67 (0.24)	0.672
Liver weight (% hot carcass weight)	3.93 (0.12)	3.51 (0.14)	0.035
Heart weight (% hot carcass weight)	0.93 (0.026)	0.85 (0.022)	0.022
Kidney weight (% hot carcass weight)	0.76 (0.015)	0.70 (0.026)	0.069

Values are means (± SE)

When comparisons were made for carcass conformation according to the EUROP score, lambs born from R ewes had a carcass with a better conformation (60%"R"- 40%"O") than those born from WF ewes (33%"R"- 67%"O").
These results partly contrast with the lack of difference in organs weight and with the increased relative fat mass reported in 1 year-old sheep born singleton (and at a similar birth weight) from mothers restricted during late gestation compared to those born from unrestricted mothers [4]. Such differences may result from the rate of post-natal growth. Indeed, at slaughter, higher masses of adipose tissue were recorded when the quality of the post-natal nutrition allowed high growth rates compensating the large differences in lambs birth weight, as a result of fetal metabolic adaptations [5]. Conversely, in the present study, lambs born from R ewes had similar birth weights to those born from WF ewes, but a slightly lower growth rate from birth to weaning. This probably resulted from a residual effect of the underfed state of restricted ewes during pregnancy on the subsequent lactation.

IV. CONCLUSION

The main results of this study show that a diet exclusively composed of a low quality/high fiber forage during the second half of twin pregnancy did not impair the success of ewes' pregnancy neither the carcass quality of their male offspring. However, the observed increase in the weight of lambs' metabolically active organs such as liver, heart and kidney may sign some metabolic adaptations to fetal nutritional restrictions that will deserve to be studied.

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