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Landau S., Zoref Z., Nitsan Z., Madar Z.

in

Purroy A. (ed.).
Body condition of sheep and goats: Methodological aspects and applications

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 27

1995
pages 161-170

The influence of processing corn grain fed to ewes during late pregnancy on birth-weight of Finn x Awassi crossbred lambs

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SUMMARY - Maximising birth-weight would improve the rate of survival of lambs especially from multiple litters. The relationship between corn starch degradability in late pregnancy diets and lambing performance was studied in 60 Finn-Awassi ewes fed diets containing 500 g/d of corn given as whole (WC), extruded (EC) or ground (GC). Lamb birth-weights ranked as follows: single lambs: EC>WC>GC (NS at 2nd parity, P<0.10 at 3rd and higher parities); twin lambs: EC>WC=GC (P<0.07 at 2nd, P<0.02 at 3rd and higher parities). The overall positive effect of EC on lamb birth-weight was significant (P<0.03). The ratio between birth-weight of twin lamb litters and maternal weight measured 4 days post-partum in ewes at 3rd and higher parities was 25% greater in EC-fed ewes than in WC- or GC-fed counterparts (P<0.03). All parities included, this ratio was 24% greater in EC than in the other groups (P<0.11). Birth-weight of single lambs, relative to maternal body-weight, was not affected by treatments. Litter birth-weight was positively correlated with maternal plasma level of non-esterified fatty acids (NEFA) and negatively correlated with plasma levels of glucose and insulin: 78% of variance in lamb birth-weight could be explained by plasma NEFA (positive correlation) and insulin (negative correlation) concentrations on day 23 pre-partum, or plasma NEFA (positive correlation), insulin and glucose (negative correlations) concentrations on day 9 pre-partum, and ewe body-weight at day 4 post-partum (positive correlation). In conclusion: (i) in prolific ewes at late pregnancy, highly degradable corn starch promotes better fetal growth than moderately degradable corn starch; (ii) the positive correlation between NEFA and lamb birth-weight, even in "overfed" ewes carrying single lambs shows that maximal lamb birth-weight is not likely to be maximised without some extent of maternal lipolysis.

Key words: Sheep, birth-weight, pregnancy, starch degradability, prolificacy.

RESUME - *"L'influence du traitement du maïs grain distribué aux brebis en fin de gestation sur le poids à la naissance d'agneaux croisés Finnois x Awassi". La maximisation du poids à la naissance augmenterait le taux de survie des agneaux, surtout nés multiples. On a étudié la relation entre la dégradabilité de l'amidon de maïs grain dans les rations de fin de gestation et les performances d'agnelage chez 60 brebis Finnois x Awassi recevant des rations contenant 500 g/j de maïs sous forme de grain entier (ME), extrudé (MEx) ou broyé (MM). Les poids des agneaux à la naissance ont été dans l'ordre : agneaux nés simples : MEx>ME>MM (NS pour les brebis de seconde parité, P<0,10 pour celles de 3ème parité et plus ; agneaux nés doubles : MEx>ME=MM (P<0,07 pour les brebis de seconde parité, P<0,02 pour la 3ème parité et plus). L'effet global de MEx sur le poids à la naissance a été significatif (P<0,03). A la 3ème parité, le rapport du poids de naissance des portées sur celui des mères 4 jours post-partum et plus a été de 25% plus élevé chez les brebis recevant MEx, que chez les brebis recevant ME ou MM (P<0,03). Toutes parités incluses, ce rapport était de 24% plus élevé pour le groupe MEx que dans les autres groupes (P<0,11). Le traitement du maïs n'a pas affecté le rapport du poids à la naissance des agneaux nés simples sur celui de leurs mères. Le poids des portées a été corrélé positivement* *avec les taux plasmatiques d'acides gras non-estérifiés (AGNE) des mères, et négativement avec les taux de glucose et d'insuline : on a expliqué 78% de la variation du poids des portées par les taux au jour 23 pre-partum de AGNE (corrélation positive) et d'insuline (corrélation négative) ou les taux au 9ème jour pre-partum de AGNE (corrélation positive), d'insuline et de glucose (corrélation négative) et le poids des brebis 4 jours àpres l'agnelage (corrélation positive). En conclusion : (i) un amidon de maïs très dégradable donné en fin de gestation a été préférable à un amidon modérément dégradable pour la croissance des foetus ; (ii) la corrélation positive des AGNE maternels et du poids des portées, même chez les brebis portant des agneaux simples et "sur-alimentées" montre que la maximisation du poids des agneaux ne peut probablement être obtenue sans lipolyse maternelle.*

***Mots-clés :** Mouton, poids à la naissance, gestation, dégradabilité de l'amidon, prolificité.*

Introduction

The uterus and fetuses utilise a great part of the glucose produced by pregnant prolific ewes (Prior and Christenson, 1978). Poor nutrition of ewes causes low glucose entry rate and impairs fetal development, but glucose infusion to fetuses may reverse fetal development to normal (Bell *et al.*, 1988). Birth-weight of lambs is positively correlated with glucose entry rate of their mothers at late pregnancy (Barry and Manley, 1985; Landau, 1994), and is important for the survival of lambs, mainly from multiple litters (Hinch *et al.*, 1985). Another component of lamb survival is the immediate availability of colostrum to new-born lambs, which is also affected by glucose entry rate (Barry and Manley, 1985). Glucose entry rate is positively correlated to the level of energy supply to sheep (Barry and Manley, 1985; Landau, 1994). High ruminal degradability of dietary starch negatively affects glucose entry rate in non-pregnant (Landau *et al.*, 1992), but not in 115 day-pregnant ewes (Landau, 1994). An increase in ruminal degradability of starch from corn grain may be obtained by processing the grain (grinding, extruding, Landau *et al.*, 1992).

To our knowledge, the effect of corn starch degradability in maternal diets on lamb birth-weight and colostrum availability post-partum has not been documented.

Energy deficiency leads to maternal lipolysis. The contribution of lipolysis to glucose formation is minimal, because only glycerol, representing about 10% of fatty tissue weight is a glucose precursor (Wilson *et al.*, 1983). Stern *et al.* (1978) suggested, but were unsuccessful to demonstrate, that minimal lipolysis, as assessed by plasma non-esterified fatty acids (NEFA) should result in increased lamb-weight. On the contrary, Leury *et al.* (1990) showed that *physical* exercise, leading to lipolysis, enhances glucose metabolism in ewes. Also, shearing during the last month of pregnancy increases NEFA levels in ewes and lamb birth-weights (Symonds *et al.*, 1988).

This study was aimed at: (i) clarifying the effects of dietary starch degradability on lamb birth weight and maternal colostrum availability at parturition; (ii) studying the interactions between changes in maternal body condition and lamb birth-weight.

Material and methods

Pregnant Finn x Awassi ewes (n=60), at second or higher parities served in this experiment. Rations were formulated according to NRC (1985) for twin-bearing sheep at the last month of pregnancy. The experimental diets were given from day 40 before parturition (on average). They included 400 g vetch hay (180 g/kg CP, 450 g/kg NDF, 377 g/kg ADF, on DM basis), 150 g of a concentrate feed containing soya-bean meal- mineral-vitamin mix (443 g/kg CP on DM basis), corn silage provided *ad libitum* (97 g/kg CP, 447 g/kg NDF, 244 g/kg ADF, on DM basis) and 500 g/d of corn grain given as whole (WC, 95 g/kg CP, on DM basis; n=19), ground (GC, 93 g/kg CP, on DM basis; n=18) or extruded (EC, 102 g/kg CP, on DM basis; n=23) from day 50 before parturition (on average). Extrusion was performed at 200°C at a pressure of 70 Bar during 22 seconds. Energy content of WC, GC and EC were derived from *in vivo* digestibility in sheep fed at maintenance level (Landau *et al.*, 1992). All foods were distributed in 2 meals at 7:00 and 16:00. Residues were collected twice a day, dried at 60ºC during 3 days and daily group DM intake was determined daily for 15 days, from day 23 to day 8 before the average date of lambing for all ewes. Ewes were weighed and scored (Russel *et al.,* 1969) before morning meal every 10 days during experiment.

Body score (BS) and weight (BW) were also monitored on day 4 after lambing. It was assumed that weight at that date reflected maternal body weight only, unbiased by pregnancy fluids. Blood was sampled at days 40 (pre-experimental), 23 and 9 pre-partum before the morning meal. Glucose was analysed in plasma, using a Beckman Glucose Analyzer 2 (Fullerton, Ca). NEFA concentration was determined according to Barash and Akov (1987), and insulin, using a kit for human insulin (International CIS, Gif-sur Yvette, France). For Insulin, within-assay and between-assays coefficients of variance were 4.1% and 12.2%, respectively. Lambs were dried and weighed immediately after birth. Before new-born lambs were allowed to suckle, dams were hand milked. Residual milk was then obtained following an intra-jugular injection of oxytocin (10 IU).

Statistical analysis

The effect of time pre-partum on group feed intake was evaluated by linear regression, with day pre-partum as source of variance. The effects of corn treatment, litter size and parity and their interactions on the duration of pregnancy, lamb birth-weight and the yield of colostrum were analysed, using the GLM procedures of SAS (1988). Analysis of variance for BW and BCS, plasma glucose, NEFA and insulin was performed by using a repeated measures procedure, with sheep (corn treatment x prolificacy) as term of error in the GLM procedure, using only 2 classes of prolificacy, i.e., single and multiple lamb litters (SAS, 1988). Relationships between lamb birth-weight, and ewe body-weight and condition, plasma concentrations of glucose, NEFA and insulin was established, using stepwise multivariable regression (SAS, 1988).

Results

Intake of corn silage significantly decreased from day 23 to day 8 pre-partum by 40 and 30 g/d in GC- and EC-fed groups (P<0.05) (Fig. 1). In WC-fed sheep this reduction (16 g/d) was not significant. Differences in silage intake resulted in small variation in the average intakes of CP and ME during the experiment (Table 1).

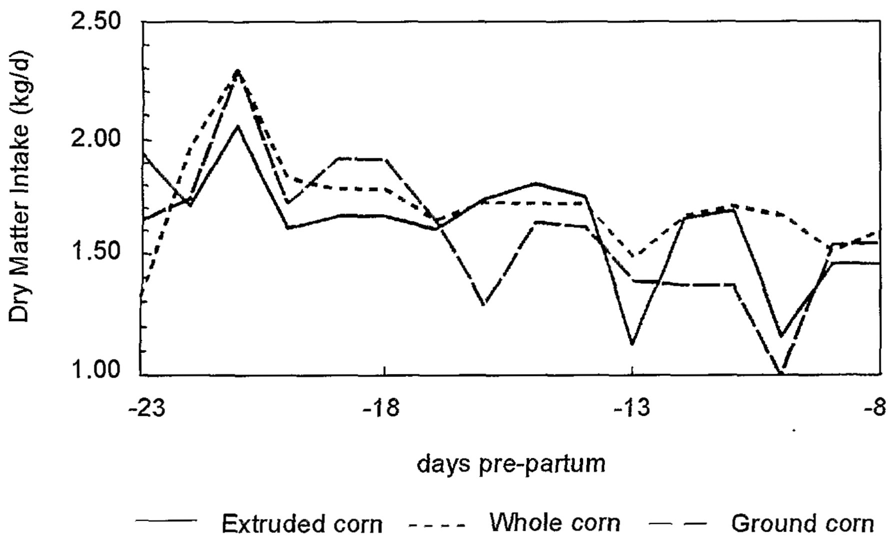

Fig. 1. Daily group intake of dry matter (kg DM/d) of pregnant ewes fed on diets with extruded (EC), ground (GC) and whole (WC) corn from day 23 to day 8 pre-partum.

Table 1. Daily intake of dry matter (DM, kg), crude protein (CP, g) and metabolisable energy (ME, MJ) in pregnant ewes fed on diets with extruded (EC), ground (GC) and whole (WC) corn (averages of 16 days, 23 to 8 pre-partum, ± SE)

	DM	CP	ME
EC	1.64 ± 0.06	231 ± 5	18.1 ± 0.6
GC	1.61 ± 0.07	228 ± 8	17.8 ± 0.7
WC	1.72 ± 0.05	238 ± 5	19.0 ± 0.5

Average litter size within ewes of the different dietary groups is shown in Table 2. The differences in litter size between nutritional treatments were not significant and were established prior to the start of experiment.

Corn treatments and prolificacy did not affect duration of pregnancy (Table 2), but 2nd parity pregnancies were shorter than 3rd and higher parities (142.9 and 145.6 days, respectively; P<0.01).

Table 2. Litter size (LS) and the duration of pregnancy (DP) of ewes in experiment: ewes were from 2nd or 3rd and higher parity and fed diets with extruded (EC), ground (GC) or whole (WC) corn grain at the end of pregnancy (least square means ± SE)

Parity\diets	EC	GC	WC
2nd	n=9	n=5	n=9
LS	1.89 ± 0.31	2.00 ± 0.42	1.56 ± 0.31
DP	144.0 ± 1.2	140.2 ± 0.6	143.6 ± 1.3
≥3rd	n=14	n=13	n=10
LS	2.50 ± 0.25	2.15 ± 0.27	1.60 ± 0.30
DP	146.1 ± 0.8	145.5 ± 0.6	145.4 ± 0.8

Main effects on DP: parity, P<0.001

BW changes from day 40 pre- to day 4 post-partum were affected by litter size (Table 3) (P<0.03). Carriers of single and twins gained 109 and 8 g/d, whereas of triplets lost 82 g/d, respectively. BW changes did not to differ between corn treatment groups.

Table 3. Body weight changes (BWC, g/day) from day 40 pre- to day 4 post-partum of Finn x Awassi ewes diets with extruded (EC), ground (GC) or whole (WC) corn grain at the end of pregnancy (least square means ± SE)

	Litter size		
	1	2	3
2nd parity			
EC	111 ± 65	54 ± 56	-88 ± 80
GC	220 ± 113	65 ± 65	56 ± 113
WC	86 ± 56	41 ± 57	
≥3rd parity			
EC	91 ± 65	52 ± 56	-157 ± 65
GC	120 ± 80	-29 ± 46	-5 ± 57
WC	110 ± 51	2 ± 57	-289 ± 113

Main effect: Litter size, P<0.003

Corn treatment and parity number had no effect on BS till day 16 pre-partum. From day 16 pre-partum onward, ewes from 2nd parity had higher BS than ewes from 3rd and higher parities (Fig. 2) (P<0.01). BS at day 4 post-partum was negatively correlated with litter size (P<0.02). Multiple lamb-carriers lost 0.5 point of BS, whereas single lamb-carriers gained 0.5 point from day 40 pre- to day 4 post-partum (Fig. 3) (P<0.001). EC- and GC-fed ewes carrying single lambs gained more BS than WC-fed counterparts (P<0.05).

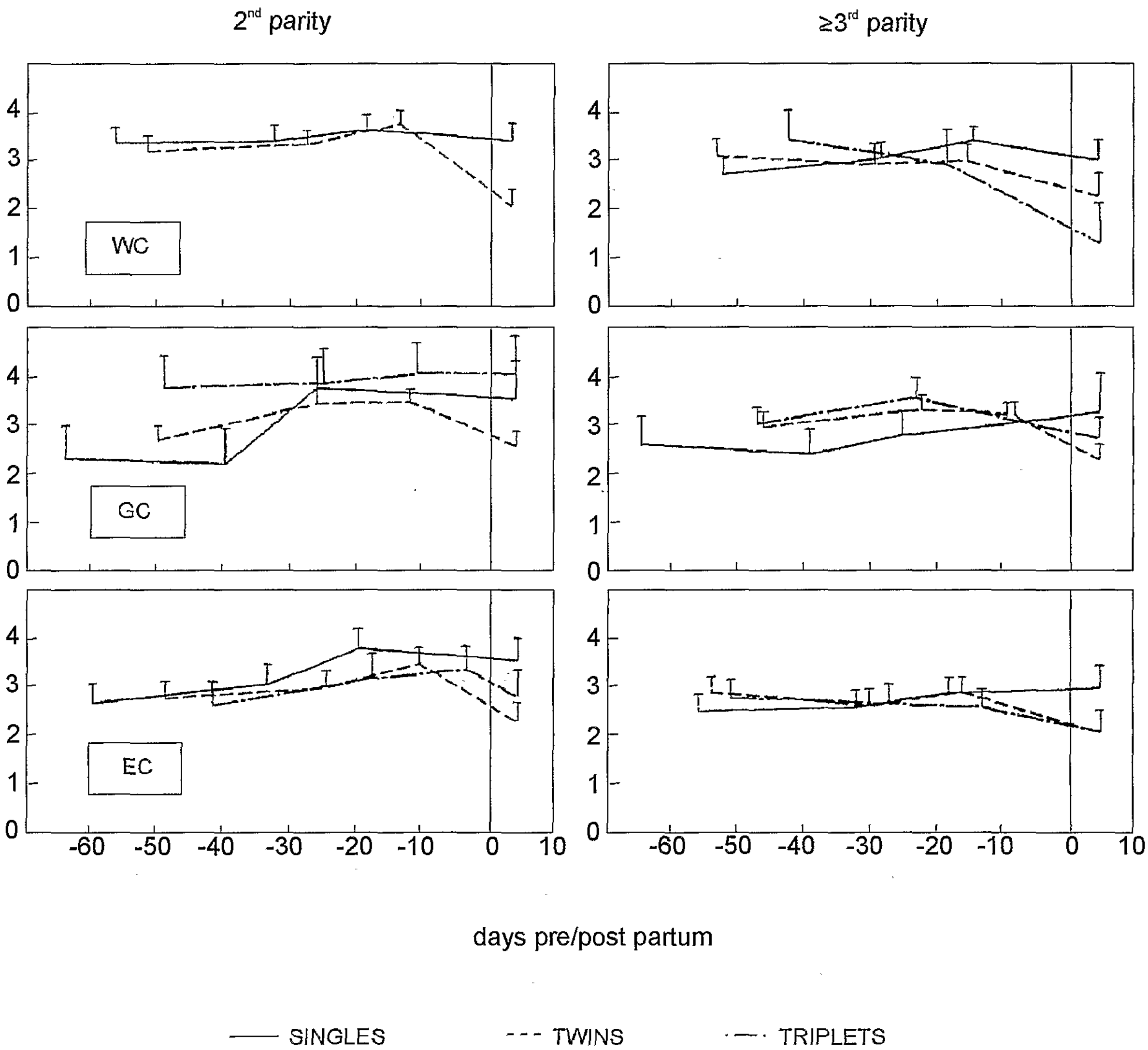

Fig. 2. Body condition score of ewes fed rations with whole (WC), ground (GC) and extruded (EC) corn until day 4 post-partum: least square means ± SE.

Analysis of variance for weights was conducted on litters of 1, 2, or 3 lambs and their mothers, only, since only EC-fed ewes gave birth to quadruplets (2 ewes) and sextuplets (1 ewe). Lambs born to ewes at third or higher parities were heavier at birth than lambs born to 2nd parity ewes (P<0.0001) (Table 4). Overall, EC-feeding was associated with higher lamb birth-weight than other diets (P<0.03). This effect was significant at P<0.02 in twin lambs from 2nd parity and at P<0.10 in single and twin lambs from 3rd and higher parities. The birth-weight of lambs born to WC- and GC-fed ewes did not differ. The ratio of litter birth-weight to the weight of mothers at day 4 post-partum was 25% higher(P<0.10) in EC-fed ewes than in ewes fed other rations but this effect was significant for ewes at 3rd and more parities only (P<0.03).

Colostrum production was recorded only if the milking procedure could be conducted before lambs suckled their dams, i.e., in 46 ewes. No dietary or litter size effects were found for colostrum availability at parturition. Ewes from 2nd parity yielded less colostrum than counterparts from 3rd and higher parities (387 and 1467 g, SE 270 g; P<0.04).

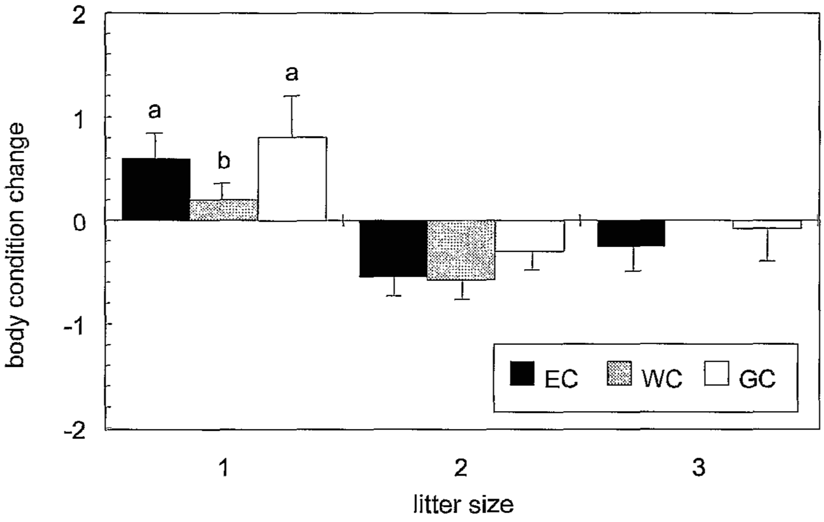

Fig. 3. Body condition score changes of ewes fed rations with whole (WC), ground (GC) and extruded (EC) corn from day 40 pre-partum to day 4 post-partum: least square means ± SE.

Table 4. Lamb birth-weights (BW, kg) and litter birth-weight relative to dam live-weight (LBW/D, g/kg) at day 4 post-partum of Finn x Awassi lambs from dams fed diets with extruded (EC), ground (GC) or whole (WC) corn grain at the end of pregnancy[†]

	Litter size					
	1		2		3	
2nd parity						
	BW	LBW/D	BW*	LBW/D#	BW	LBW/D
EC	4.4 ± 0.4	66 ± 11	3.3 ± 0.2[a]	103 ± 10[a]	2.3 ± 0.3	110 ± 14
GC	3.4 ± 0.7	40 ± 20	2.5 ± 0.3[b]	79 ± 11[b]	2.4 ± 0.4	100 ± 20
WC	3.4 ± 0.3	59 ± 10	2.7 ± 0.2[b]	80 ± 9[b]		
≥3rd parity						
	BW#	LBW/D	BW#	LBW/D*	BW	LBW/D
EC	4.8 ± 0.3[a]	52 ± 11	4.1 ± 0.2[a]	127 ± 10[a]	3.5 ± 0.2	136 ± 11
GC	3.6 ± 0.5[b]	54 ± 14	3.7 ± 0.2[ab]	106 ± 7[ab]	3.4 ± 0.2	128 ± 10
WC	4.5 ± 0.3[ab]	57 ± 11	3.5 ± 0.2[b]	95 ± 10[b]	3.0 ± 0.4	122 ± 20

[†]Within columns within parities separately, means with a common supercript do not differ (*P<0.05; #P<0.10; a,b: P<0.05)
Main effects on BW: corn treatments, P<0.03; Litter size, P<0.0001; parity, P<0.0001
Main effects on BW/D: corn treatments, P<0.10; Litter size, P<0.0001; parity, P<0.0001

Changes in plasma glucose, NEFA and insulin are shown in Fig. 4. Results of 2nd and higher parities, and of GC and WC diets (shown as WC in Fig. 4) were pooled together because there were no differences between them. Glucose concentration tended to increase from day 40 to day 23 pre-partum (P<0.06) and remained at the same level till day 9 pre-partum except for a marked increase in EC-fed sheep carrying triplets. Diets, parity and litter size did not affect consistently *glucose concentrations*. Plasma NEFA was lowest in the EC group for all litter size groups before the experiment started. On day 23 pre-partum, NEFA was higher in EC than in WC or GC-fed sheep (P<0.05) and remained higher till day 9 pre-partum within all groups of litter size. Triplet carriers had highest plasma NEFA from day 23 before parturition onward. Significant "sheep" (P<0.002), litter size (P<0.03), "days pre-partum" (P<0.01) and "corn treatment x days pre-partum" (P<0.005) effects on NEFA levels were found. An increase in insulin levels was noted from day 40 to day 23 pre-partum, at the exception of EC-fed triplet-carriers. From day 23 to day 9 pre-partum, plasma insulin increased in single lamb-carriers only (P<0.05). Significant effects of "individual sheep", "time to parturition" (P<0.003) and "corn treatment x time to parturition" (P<0.001) on insulin levels were found. A negative relationship was found between litter size and insulin at day 9 pre-partum (P<0.01).

Multivariable regression analyses showed that combinations of NEFA and insulin, or NEFA and glucose accounted for 92% and 48% of variance in birth-weights of single and multiple litters, respectively, at day 23; and 86% and 48% of the same parameters, at day 9 pre-partum (Table 5). Maternal body-weight at day 4 post-partum, i.e., unbiased by uterine fluids, was positively correlated with birth weight of multiple, but not of single lamb litters.

Models which included maternal body-weight at day 4 post-partum, insulin and NEFA at day 23; or maternal body-weight at day 4 post-partum, insulin, NEFA and glucose at day 9 before parturition explained 77% and 78%, respectively (P<0.0001) of the variance in litter birth-weight.

Discussion

The present study provides evidence that energy intake is not the only factor affecting litter weight in prolific ewes, because physical treatment of the grains affected litter weight almost without effect on maternal energy intake. Two mechanisms may probably help understand this phenomenon.

One possible explanation is enhanced glucose metabolism in ewes fed EC, as compared with WC. EC-feeding generates higher amounts of ruminal propionate than WC-feeding (Landau *et al.*, 1992). Pregnant ewes fed EC had greater glucose entry rates than WC-fed counterparts (Landau, 1994). On the contrary, feeding WC elicited higher glucose entry rate in non-pregnant ewes (Landau *et al.*, 1992) and more ovulations (Landau *et al.*, 1995) than feeding EC. The discrepancy between results obtained with pregnant and non-pregnant sheep may be explained by the higher ability of the former to synthesize glucose from propionate (Wilson *et al.*, 1983). Supporting evidence is that insulin levels were not significantly higher in EC-fed than in WC-fed pregnant sheep (Fig. 4), contrarily to our previous finding in non-pregnant sheep fed at 1xM (Landau *et al.*, 1992).

A second explanation is connected with increased lipolysis in EC-fed ewes. This explanation is backed by higher NEFA levels in EC-fed ewes bearing multiple litters than in corresponding WC- or GC-fed ewes (Fig. 4). However, this seems to be a very short-term effect because it did not reflect in BS changes. The positive effect of maternal lipolysis seems to be backed by the finding that NEFA levels were strongly correlated with litter birth-weight. The finding that single-lamb birth-weight is related to maternal lipolysis is particularly unexpected, because all ewes had access to feed provided at two maintenance level, i.e., to large excess of energy for those bearing single lambs (NRC, 1985). The high correlation between maternal body-weight at day 4 post-partum and the birth weight of multiple-born, but not single-born lambs support the hypothesis that uterine limitations impaired development of multiple, but not single lambs. Stern *et al.* (1978) tried to eliminate maternal lipolysis by adjusting energy intake to maternal NEFA levels. This did not increase, but rather reduced the birth-weight of twins, but not of single lambs. Kleeman *et al.* (1993) showed that fetal growth was not enhanced by short-term supplementation of concentrates to Booroola ewes at the end of pregnancy. Symonds *et al.* (1988) and Leury *et al.* (1990) respectively showed that shearing ewes at the end of pregnancy, or subjecting them to physical exercise, thus promoting maternal lipolysis, increased lamb birth-weight.

It seems therefore that some extent of lipolysis is necessary to maximize lamb birth-weight. This could be related to the finding by Aiello and Armentano (1988) that oleic acid is essential to maximize gluconeogenesis in isolated hepatocytes. The practical use of this theory would be to restrict energy intake by prolific ewes at the end of pregnancy. Additional research is needed to complete quantitative information about timing, duration and extent of this restriction.

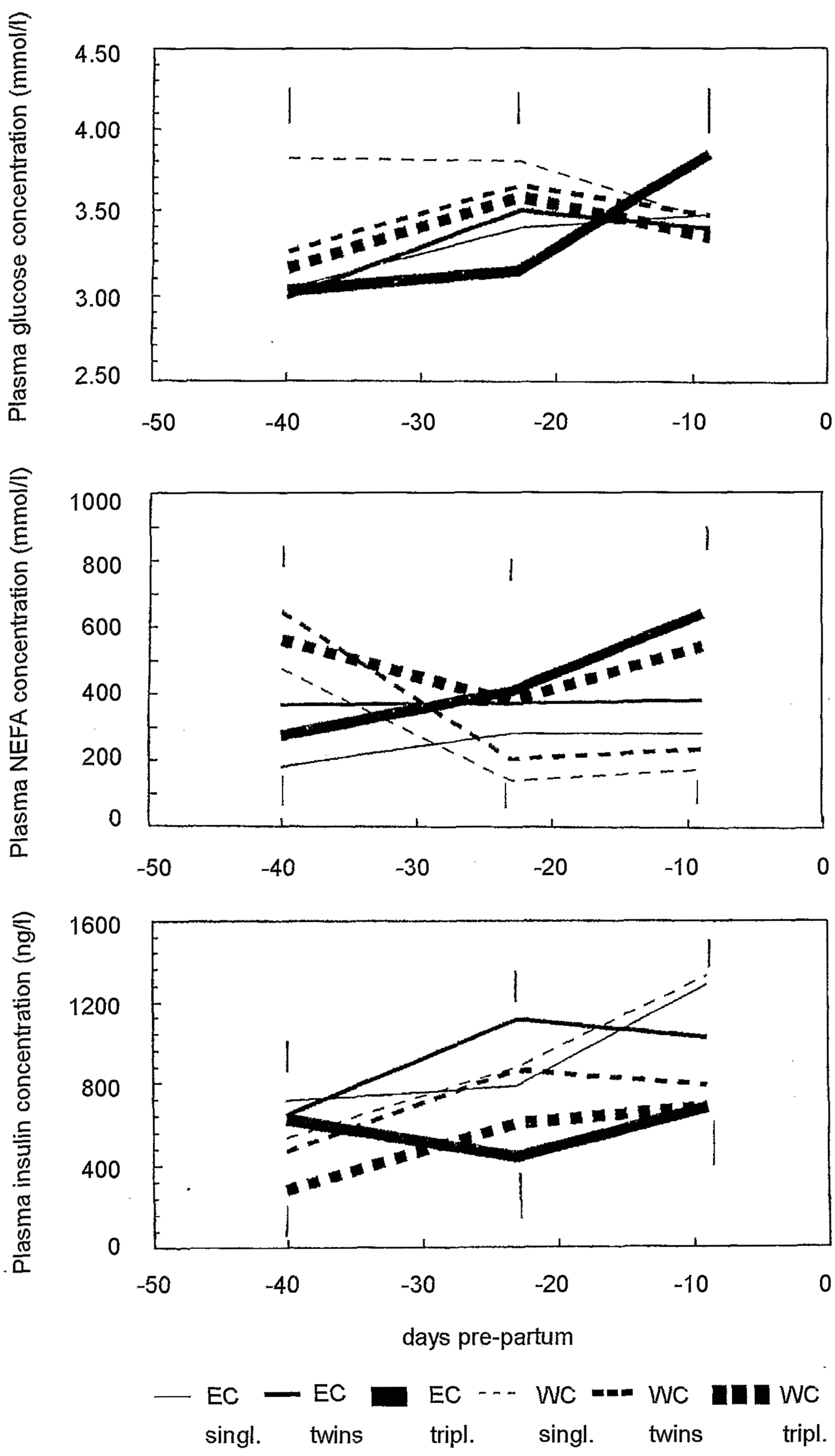

Fig. 4. Glucose (mmol/l), non-esterified fatty acids (NEFA, µmol/l) and insulin (ng/l) concentrations in the plasma of ewes fed rations with whole (WC), ground (GC) and extruded (EC) corn during 40 days pre-partum: least square means ± SE.

Table 5. The relationships between maternal body-weight (BW) and body score (BS) at day 4 post-partum, plasma glucose (G), non-esterified fatty acids (NEFA) and insulin (I) at days 23 and 9 pre-partum and the weight of litters of different litter size (LS), as determined by multivariable stepwise regression and the cumulative coefficient of determination (R^2_{++})

LS	1					≥2					All				
	BW	BS	G	NEFA	I	BW	BS	G	NEFA	I	BW	BS	G	NEFA	I
Day 23 P<				+ 0.04	- 0.07	+ 0.001	- 0.002		+ 0.10		+ 0.001			+ 0.01	- 0.04
		R_0^2=0.92* R^2=0.92*					R_0^2=0.48* R^2=0.85**					R_0^2=0.52** R^2=0.78***			
Day 9 P<		- 0.10	- 0.08			+ 0.002		- 0.003	+ 0.02		+ 0.01		- 0.04	+ 0.001	- 0.06
		R_0^2=0.85# R^2=0.85#					R_0^2=0.48* R^2=0.76**					R_0^2=0.58** R^2=0.77***			

Positive and negative effects on litter birth-weight are labeled + or -, respectively. Parameters not labeled with + or - did not enter stepwise regressions at the P<0.15 level. The number under +/- labels indicate level of significance of partial R^2

R_0^2: Coefficient of determination when model includes G, NEFA, I; R_2 also includes BW and BS

# P<0.10;*P<0.05;**P<0.01;***P<0.0001

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