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Homeorhetic hormones, metabolites and accelerated growth

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Six newly weaned karakul ewes, three with fat tails and three without tails, were used to investigate the metabolic and hormonal changes during accelerated growth. Two lambs acted as controls, while the remaining four were subjected to a maintenance diet for two weeks. The subsequent resumption of *ad lib* feeding caused a period of accelerated growth for approximately four days before the normal growth pattern resumed.

Blood samples were drawn from surgically implanted catheters in the caudal aorta and vena cava during normal growth, maintenance (zero) growth and accelerated growth. These samples were assayed for glucose, free fatty acids, glycerol, alanine, lysine, growth hormone, insulin and thyroxine.

It was found that during the period of accelerated growth, glucose concentrations decreased after feeding while free fatty acids and glycerol concentrations increased after feeding. This is the inverse of the normal growth pattern. The uptake of lysine was doubled during accelerated growth, while alanine concentrations did not change significantly.

Growth hormone concentrations dropped during accelerated growth and increased dramatically during the subsequent normal growth phase, while insulin concentrations increased during accelerated growth. Thyroxine concentrations increased during accelerated growth and dropped during the subsequent normal growth phase.

Ses pas gespeende karakul ooie, drie met sterte en drie sonder sterte is gebruik om die moontlike veranderings in metaboliete en hormone waar te neem, tydens versnelde groei. Twee skape is as kontroles gebruik, terwyl die oorblywende vier blootgestel is aan 'n dieet wat net genoegsaam is vir onderhoud vir twee weke. Daaropvolgens is 'n *ad lib* dieet gegee wat 'n periode van versnelde groei veroorsaak het vir ongeveer vier dae, voordat normale groei weer in werking getree het.

Bloedmonsters is getrek uit kateters wat deur chirurgiese metodes in die kaudala aorta en vena cava ingeplant is. Bloed is getrek tydens drie fases: normale groei, onderhoud en versnelde groei. Hierdie monsters is ontleed vir glukose, vry vetsure, gliserol, alanien, lisien, groeihormoon, insulien en tiroksien.

Gedurende die periode van versnelde groei is gevind dat glukosekonsentrasies verminder na voeding terwyl vetsure en gliserolkonsentrasies vermeerder. Dit is die teenoorgestelde patroon van dié van normale groei. Die opname van lisien was dubbeld gedurende versnelde groei terwyl alanienkonsentrasies nie beduidend verander het nie.

Groeihormoonkonsentrasies val gedurende versnelde groei maar vermeerder dramaties gedurende die daaropvolgende normale groeifase, terwyl insulienkonsentrasies vermeerder gedurende versnelde groei. Tiroksienkonsentrasies vermeerder gedurende versnelde groei en val dan weer in die daaropvolgende normale groeifase.

Keywords: Karakul ewes, accelerated growth, growth hormone, free T4, glucose, free fatty acids, glycerol, alanine, lysine

Introduction

Compensatory or accelerated growth has been well documented in farm animals and is thought to be the result of heightened metabolic acitivity after a phase of accelerated growth. However, very little is known about the changes which occur in levels of metabolites and hormones during accelerated growth. Hence, the present study investigated the concentration and flux of metabolites and hormones across the hindquarter of karakul ewes during normal, maintenance (zero) and accelerated growth. Blood samples taken before and after feeding during these three phases were assayed for growth hormone, insulin, free thyroxine (T4), glucose, free fatty acids (FFA), glycerol, alanine and lysine.

Materials and Methods

Animals

Six newly weaned karakul ewes 12 to 14 weeks old were used. Three lambs were allowed to retain their fat tails to determine the possible influence of adipose tissue on the metabolism of the hindquarter during growth and the other three had their tails surgically removed. Two of the lambs acted as controls, one with a tail and one without.

Diet

The lambs were fed *ad lib* on a medium concentrate diet (68% lucerne hay, 30% maize meal and 2% fish meal). Residues of this diet were weighed daily to obtain the average daily intake for each lamb. This intake was halved for two weeks to cause the maintenance phase of growth. The subsequent resumption of *ad lib* feeding caused accelerated growth for approximately four days before normal growth resumed (Figure 1).

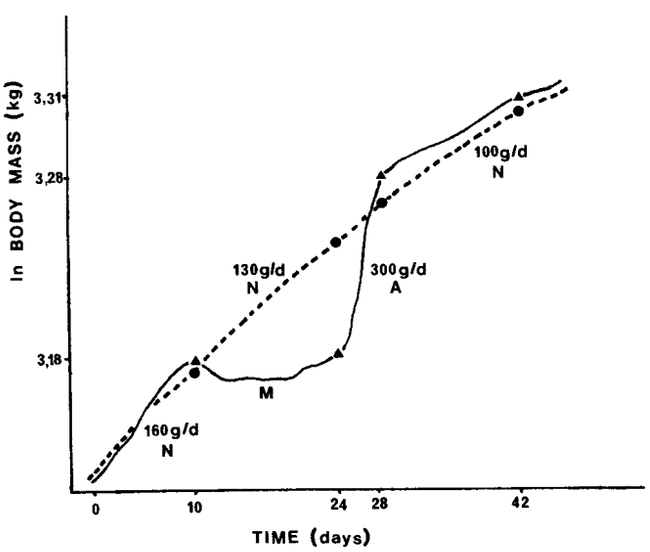

Figure 1 Growth curves of karakul ewes for control animals (● --- ●) fed *ad lib* for the duration of the experiment compared to experimental animals (▲—▲) during *ad lib* feeding (normal growth, N), half *ad lib* feeding (maintenance or zero growth, M) and after resumption of *ad lib* feeding (accelerated growth, A followed by normal growth, N)

Sampling

Blood sampling was done via surgically implanted PVC catheters in the caudal aorta and vena cava. Four pairs (arterial and venous) of samples were taken at half hourly intervals before the ration was offered at 08h00, and four pairs from 10h00 onwards.

Metabolite assays

Glucose concentrations were assayed using a commercial glucose oxidase kit (Boehringer Mannheim). Free fatty acid concentrations were determined colorimetrically (de Villiers *et al.*, 1977). Glycerol, alanine and lysine concentrations were determined enzymatically (Pinter *et al.*, 1967; Reilly, 1975; and Nakatani *et al.*, 1972, respectively).

Hormone assays

Insulin and free thyroxine concentrations were measured by radio-immuno-assay (RIA) using commercially available kits (Diagnostics Products Corporation). Growth hormone was assayed by RIA using ovine growth hormone iodinated in the laboratory, and rabbit serum (anti- O GH-serum) was used as the antiserum.

Results and Discussion

Glucose

An obvious trend in both groups of sheep was the increase in glucose fluxes of *ca.* 2 mM/h/kg^{0,75} after the ration had been offered, except during the accelerated phase where exactly the opposite took place. The arterial as well as venous concentrations remained remarkably constant in all the sheep.

There was a constant uptake of glucose by the hindquarter during all the growth phases of between 1 and 3 mM/h/kg^{0,75} glucose. Values for the glucose flux have been normalized to a control value of 100 and are shown in Table 1. The pattern of the Δ values (arterial-venous difference) shows that concentrations were lower than control values during maintenance and increased dramatically during accelerated growth. The sheep with tails showed an increase in glucose concentration during the pre-feeding phase of normal growth.

The extraction ratios of glucose relative to the arterial concentrations remained between 4% and 11% during all growth phases in all the sheep.

Table 1 Glucose flux across the hindquarter of sheep with and without fat tails during maintenance, accelerated and normal growth. Each result has been normalized to its own control value of 100

	Sheep without tails[a]			Sheep with tails[a]		
Growth phase and sampling time	A	V	Δ	A	V	Δ
Maintenance						
pre-feeding	40	42	−48	2	−0,3	36
post-feeding	34	44	−26	3	8	−50
Accelerated						
pre-feeding	18	15	65	14	4	11
post-feeding	12	9	75	6	3	114
Normal						
pre-feeding	16	16	26	27	23	148
post-feeding	21	9	–	35	40	−20

[a]A arterial
V venous
Δ arterial−venous

Free fatty acids and glycerol

These two metabolites followed the same general trend, as would be expected. The arterial and venous fluxes of FFA and glycerol show a consistent decrease (0,9 mM/h/kg^{0,75} and 0,2 mM/h/kg^{0,75}, respectively) during all the phases except accelerated growth where there is a significant increase after feeding. This is the inverse of the glucose results.

The high FFA fluxes (up to 4,5 mM/h/kg^{0,75}) during the maintenance pre-feeding period in both groups of sheep were dramatically reduced by the increased feed intake during accelerated growth. There was a consistent output of FFA and glycerol in all the sheep (*ca.* 0,5 mM/h/kg^{0,75}, respectively).

Table 2 shows the relative FFA flux normalized to a control value of 100. The Δ values on this table show a decrease over the control values during accelerated growth and an increase, especially in the sheep with tails, during the maintenance period. The high values in normal growth indicate that the lambs were in a metabolically accelerated condition.

Table 2 Free fatty acid flux across the hindquarter of sheep with and without fat tails during maintenance, accelerated and normal growth. Each result has been normalized to its own control value of 100

	Sheep without tails			Sheep with tails		
Growth phase and sampling time	A	V	Δ	A	V	Δ
Maintenance						
pre-feeding	111	95	36	340	316	195
post-feeding	64	74	101	90	171	510
Accelerated						
pre-feeding	−74	−75	−76	−45	−28	–
post-feeding	6	−17	−130	87	131	–
Normal						
pre-feeding	46	54	134	−15	1	16
post-feeding	−3	1	16	39	48	152

Lysine and alanine

There was a decrease of *ca.* 0,1 mM/h/kg^{0,75} in lysine levels after feeding in all the sheep, experimental as well as control. A consistent uptake of *ca.* 0,8 mM/h/kg^{0,75}lysine by the hindquarter was found in all the growth phases, especially during accelerated growth where the concentrations doubled. In the group with tails, the uptake of lysine increased despite the maintenance diet and increased even further on the *ad lib* diet during accelerated growth.

The lysine flux relative to a normalized control value of 100 is given in Table 3. Again a dramatic increase in Δ values during accelerated growth is apparent.

The sheep without tails showed a consistent increase in alanine concentration after eating in all three phases, while the sheep without tails showed a decrease. There was a general uptake of approximately 0,05 mM/h/kg^{0,75} alanine by the hindquarter; this being especially apparent in the sheep with tails.

Table 3 Lysine flux across the hindquarter of sheep with and without fat tails during maintenance, accelerated and normal growth. Each result has been normalized to its own control value of 100

Growth phase and sampling time	Sheep without tails			Sheep with tails		
	A	V	Δ	A	V	Δ
Maintenance						
pre-feeding	13	14	8	−89	−23	–
post-feeding	−19	5	−76	−22	−28	–
Accelerated						
pre-feeding	15	−26	924	116	−9	269
post-feeding	26	−2	152	11	31	477
Normal						
pre-feeding	−2	−13	67	−3	7	−80
post-feeding	−4	6	−44	23	12	483

Hormones

Table 4 shows the hormone (growth hormone (GH), insulin and thyroxine) concentrations of the experimental sheep during the three growth phases.

Growth hormone concentrations in the control sheep decreased shortly after feeding by *ca.* 0,1 ng/ml. These concentrations also decreased in the experimental sheep after feeding during maintenance and normal growth, but, during accelerated growth there was a significant increase of 0,1 ng/ml growth hormone. The control sheep showed a consistent increase (0,7 to 0,9 ng/ml) during the experimental series, but the experimental sheep showed a decrease in GH during accelerated growth followed by a sharp increase during the subsequent normal phase.

Insulin concentrations increased after feeding, in the control sheep and in the maintenance and normal phases of the experimental sheep. However, accelerated growth caused insulin concentrations to decrease (*ca.* 2μIu/ml) after feeding. These results are the inverse of the growth hormone results. The maintenance diet caused insulin concentrations to decrease to 3 μIu/ml, while subsequent *ad lib* feeding caused these concentrations to return to a normal concentration of *ca.* 6 μIu/ml.

There was no significant difference in thyroxine concentrations after the sheep were fed, in the control as well as the experimental animals. Thyroxine concentrations in the control sheep remained constant *ca.* 125 nM/l, while the dietary restriction imposed on the experimental animals caused T4 concentrations to drop during the maintenance phase. During accelerated growth T4 concentrations rose by *ca.* 10 nM/l, and the subsequent normal growth phase resulted in a drop of over 20 nM/l.

Table 4 Hormone concentrations of experimental sheep during maintenance, accelerated and normal growth

Hormone and sampling time	Growth phase		
	Maintenance	Accelerated	Normal
Growth hormone (ng/ml)			
pre-feeding	0,8	0,5	3
post-feeding	0,7	0,6	2
Insulin (μIU/ml)			
pre-feeding	3	6	6
post-feeding	5	4	8
Thyroxine (nM/l)			
pre-feeding	114	123	95
post-feeding	114	121	92

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