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Body chemical composition and utilization of dietary energy by male Saanen kids fed either milk to satiation or solid complete feeds with two proportions of straw

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SUMMARY

Of 41 male kids, 14 were killed immediately after birth (3·3 kg BW); the remainder were either fed on goat milk to satiation or weaned at 10 kg BW. After achieving 15·7 kg BW, weaned kids were fed on complete diets including either 20 or 40% straw. Milk-fed kids were slaughtered at 16·8 or 26·7 kg BW, weaned kids at 15·7 or 29–30 kg BW, respectively (at least four kids per treatment). Empty BW as a proportion of final live BW was $0·91 \pm 0·02$ in milk-fed kids compared to $0·85 \pm 0·04$ and $0·76 \pm 0·04$ in kids given complete feeds including 20 or 40% straw, respectively. Empty BW of kids in the heaviest groups were *c*. 24 kg for milk-fed or weaned kids. Energy and crude protein contents per kg empty BW increased from 4·5 MJ and 158 g in newborn kids to 12·2 MJ and 163 g in milk-fed kids or 10·4 MJ and 194 g in weaned kids, respectively. No influence of the feeding system was found on mineral contents of empty BW. Ca, P and K remained constant at 12·6, 7·7 and 1·9 g/kg, Mg increased from 0·32 to 0·46 g/kg and Na decreased from 2·0 to 1·3 g/kg. Differences in composition of live BW gain are mainly caused by differences in gut-fill. Efficiency of utilization of ME for growth was *c*. 0·75 in milk-fed kids even at high BW, but only 0·31 in weaned kids. Proportions retained of dietary N, Ca, P, Mg, Na and K were highest in milk-fed kids between birth and 16·8 kg BW: 0·57, 0·88, 0·78, 0·40, 0·37 and 0·10, respectively. They were lowest in kids fed on complete feed including 40% straw from 15·7 to 30·3 kg BW: 0·25, 0·26, 0·32, 0·04, 0·11 and 0·04, respectively. Weaning seems to be of greater influence on composition of BW gain and efficiency of utilization than the increase in empty BW.

INTRODUCTION

Recommendations in different countries for supply of energy, protein and major minerals to farm animals are based on the factorial approach since the first report of the ARC (1965) which requires knowledge of the composition of the respective product, the conceptus, body mass or milk, as well as efficiency of utilization of dietary energy and nutrients. Comparatively little information concerning body composition of goats is available in the literature. Recent estimates (AFRC 1997) on composition of empty body weight gain in milk-fed kids and of liveweight gain in weaned kids had to be based on only two and three studies, respectively. Nutritional factors such as dietary energy concentration or level of feeding could not be considered. Some recommendations for growing goats, particularly regarding mineral supply, are based on comparisons with body composition of sheep and cattle (Jarrige 1988; AFRC 1997).

This paper describes the body chemical composition of newborn kids and male kids weighing up to 30 kg which had been fed on goat milk either to satiation until slaughter or in restricted quantities until weaning at 10 kg body weight (BW). As feed intake was measured in most of these kids, efficiency of utilization of dietary energy as well as protein and major minerals can be presented for kids which either had been kept in the pre-ruminant stage or had completely developed to the ruminant stage physiologically.

MATERIALS AND METHODS

All goats were of the Saanen-type German Improved White Goat breed. Fifteen male kids (twins of seven

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does and one singleton) were not suckled and were killed *c*. 20 min after birth by the use of chloroform. Their bodies were stored at −18 °C until further analyses. All other kids were left with their does to suckle on the day of birth.

On their second day of life, kids were separated and milk was given from buckets twice daily to satiation. Consumption was recorded individually from weighing the buckets before and after each meal. For 5 days, each kid was offered the milk of its own mother, and thereafter bulked milk of the complete flock was their predominant feed. Consumption of straw from the bedding could not be quantified.

Three experiments were carried out in consecutive years. General care, handling and maintenance of the animals followed the procedures approved by the Animal Welfare Commissioner of the University of Bonn in accordance with German Animal Welfare Law. Kids were kept on straw bedding, two or three per pen, in Expts 1 and 2. Kids always had free access to tap water. Each experiment included only two treatments.

Experiment 1

Kids were fed individually on goat milk to satiation until reaching an approximate BW of either 17 or 27 kg (four kids per treatment).

Experiment 2

Kids were either fed on goat milk to satiation (six kids) or were restricted to daily quantities of 1000 g milk until 7 kg BW, 800 g milk from 7 to 8 kg BW and 600 g milk until 10 kg BW when they were weaned completely (five kids, one of which had to be removed during the experiment). Kids of both groups had free access to a concentrate mixture containing 600 g/kg dry beet pulp, 200 g/kg tapioca, 170 g/kg soya bean oil meal and 30 g/kg premix and to hay. Slaughter weight of the kids fed on milk to satiation was equal to that of the first group of Expt 1.

Experiment 3

Kids were weaned at 10 kg BW according to the procedure of the second group in Expt 2. Until 15 kg BW they were fed on a complete diet containing 30% straw, after which their complete diets given until *c*. 30 kg BW contained either 20 or 40% straw and 80 or 60% of a mixture containing 730 g/kg dry beet pulp, 150 g/kg maize gluten, 90 g/kg tapioca and 30 g/kg premix (four kids per treatment). The diets were calculated to meet the recommendations of the NRC (1981). After weaning, kids were kept individually in pens on slatted floors without straw bedding. Therefore, total intake could be quantified. In the course of the experiment each kid was transferred into a metabolism crate twice for periods of 1 week for the quantitative collection of faeces.

Intact male kids were used in Expts 1 and 3, male kids in Expt 2 were castrated in their third week of life.

Weekly samples of bulked milk were freeze-dried; samples of faeces collected in Expt 3 were oven-dried at 60 °C before further analysis.

During the 17 weeks of Expt 1, total solids concentration of the bulked milk of the flock gradually decreased from 14·0 to 11·0%. The composition of solids of this milk varied little. Only mean values of the composition of milk are given in Table 1, together with the analysed chemical composition of concentrates given in Expt 2 and both complete feeds used in Expt 3, respectively.

The metabolizable energy (ME) in goat milk given to kids has been found to be 96% of gross energy (GE) (Sanz Sampelayo *et al*. 1988). The measured GE in milk, therefore, was multiplied by 0·96 to give ME. The ME in ruminant feeds may be calculated by use of the equation of Kirchgessner (1995):

$$\begin{aligned} ME = {} & 0{\cdot}0312 \times DXL + 0{\cdot}0136 \times DXF + 0{\cdot}0147 \\ & \times (DOM - DXL - DXF) + 0{\cdot}00234 \times XP \quad (1) \end{aligned}$$

where ME = ME of feed (MJ/kg), DXL = digestible total lipids (g/kg), DXF = digestible crude fibre (g/kg), DOM = digestible organic matter (g/kg) and XP = N × 6·25 (g/kg).

At the end of each experiment, kids were stunned using a captive bolt pistol and bled by severing the carotid arteries. After the body had been opened, digestive tract and urine bladder were removed, emptied and returned together with the clotted blood into the body cavity before bodies were frozen at −18 °C. Frozen bodies of kids were cut into pieces by use of a band saw, autoclaved at 120 °C and 196 kPa for 6 h and then homogenized by use of a grinder. Representative samples of body homogenates were freeze-dried and pulverized before being analysed.

Analyses of feeds, faeces and body homogenates were performed according to official methods (Naumann & Bassler 1976): dry matter (DM) – residue after drying at 105 °C; ash – residue after ignition and heating at 550 °C; crude protein – total N after macro-Kjeldahl × 6·25; total lipids – extraction with petroleum ether; heat of combustion – adiabatic bomb calorimetry (IKA C 400). Minerals were determined from HCl-extracts of ash: Ca, Mg, Na and K – atomic absorption-spectro-photometry (Perkin Elmer), P – vanado-molybdate-colorimetry (Beckman DB-G).

Statistical significance of differences in performance between the two groups within each experiment was tested by *t*-test. Results of all whole body analyses were subjected to ANOVA procedures. Scheffé's test was applied to detect significant treatment effects (Sachs 1984). The level of significance chosen was $P \leqslant 0{\cdot}05$.

Table 1. *Chemical composition of goat milk and solid feeds given to German Saanen kids* (*on a wet weight basis*)

	Goat milk*	Concentrate mixture	Complete feed	
			20% straw	40% straw
Dry matter (%)	11·8 ± 0·270	91·0	92·0	92·0
GE (MJ/kg)	2·91 ± 0·070	17·5	18·6	18·6
Crude protein (%)	2·98 ± 0·090	17·4	13·9	11·7
Total lipids (%)	3·60 ± 0·121	1·0	4·1	3·6
Crude fibre (%)	—	8·0	11·6	23·4
N-free extract (%)	4·52 ± 0·056	64·6	56·1	47·0
Crude ash (%)	0·76 ± 0·009	8·4	6·2	6·3
Ca (%)	0·130 ± 0·0002	N.D.†	0·80	0·81
P (%)	0·088 ± 0·0002	N.D.	0·39	0·38
Mg (%)	0·011 ± 0·0002	N.D.	0·18	0·19
Na (%)	0·028 ± 0·0005	N.D.	0·14	0·13
K (%)	0·152 ± 0·0038	N.D.	0·52	0·56

* Mean ± S.E. of 17 samples analysed at weekly intervals.
† N.D. = not determined.

RESULTS

Milk consumption and growth rates of kids in the two groups of Expt 1 did not differ significantly until 16·8 kg BW, when the kids of one group were slaughtered (Table 2). Kids of the other group increased their daily milk consumption from *c*. 2·0 to 3·3 kg ($P \leqslant 0{\cdot}05$) and continued to grow at constant rates, resulting in higher milk/gain ratios. The greater standard deviations in milk consumption and final weight of the second group of Expt 1 resulted from greater differences in milk consumption between animals in the final phase. Until reaching 16·8 kg BW, this group had been as uniform as the other group.

Daily milk consumption of these kids which were fed on milk to satiation in Expt 2 was similar to daily

Table 2. *Performance of German Saanen kids either fed on milk to satiation until slaughter* (*S*) *or weaned at 10 kg BW* (*W*) (*Means* ± *S.E.*)

Experiment…	1		2		3	
Sex of kids…	Male		Castrate		Male	
Number of kids…	4	4	6	4	4	4
Feeding group…	S	S	S	W	W (20% straw)	W (40% straw)
BW (kg)						
At birth	3·1 ± 0·38	3·2 ± 0·25	3·7 ± 0·29	3·8 ± 0·30	3·1 ± 0·25	3·1 ± 0·35
At start	3·1 ± 0·38	16·8 ± 0·54	3·7 ± 0·29	3·8 ± 0·30	15·3 ± 0·31	15·0 ± 0·36
At end	16·8 ± 0·19	26·7 ± 2·05	16·9 ± 0·20	15·7 ± 0·25	29·0 ± 1·14	30·3 ± 0·22
Duration (days)	63 ± 5·5	40 ± 3·1	52 ± 0·4	66 ± 0·45	51 ± 5·8	66 ± 5·3
Intake (g/day)						
Milk	1976 ± 88·0	3300 ± 411·5	2012 ± 4·9	837 ± 25·2	—	—
Concentrates	—	—	31 ± 3·3	239 ± 18·4	—	—
Complete feed	—	—	—	—	1100 ± 35·4	1194 ± 65·4
Total consumption (kg)						
Milk	123 ± 9·1	132 ± 22·5	104 ± 2·5	34 ± 1·5*	—	—
Concentrates	—	—	1 ± 0·1	15 ± 1·1	—	—
Complete feed	—	—	—	—	56 ± 7·6	78 ± 3·1
BW gain (g/day)	226 ± 16·8	240 ± 40·2	272 ± 5·7	185 ± 6·2	272 ± 18·2	236 ± 20·4
Milk/gain ratio	8·9 ± 0·55	14·2 ± 1·03	7·4 ± 0·16	4·5 ± 0·05	—	—
Concentrate/gain ratio	—	—	0·08 ± 0·012	1·28 ± 0·125	—	—
Complete feed/gain ratio	—	—	—	—	4·1 ± 0·31	5·1 ± 0·19

* Milk was offered only for 41 days.

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Table 3. *Digestibility* (*mean* ± S.E., *n* = *4*) *and ME in two complete feeds for German Saanen kids* (*Expt 3*)

	Type of complete feed		
	20% straw	40% straw	Significance of difference
Digestibility* (%) of			
Organic matter	77 ± 1·1	59 ± 2·5	$P \leqslant 0.001$
Total lipids	54 ± 1·5	49 ± 2·0	$P \leqslant 0.05$
Crude fibre	52 ± 1·2	55 ± 0·9	$P \leqslant 0.05$
ME† (MJ kg^{-1} DM)	14·4	11·2	

* Determined from two 7-day faecal collections per kid.
† Calculated from digestible crude nutrients using Eqn (1).

consumption of kids in Expt 1 between birth and 16·8 kg BW. These kids drank *c*. 2 kg milk daily and consumed hardly any concentrates. Rates of daily BW gain of kids fed on milk to satiation up to almost 17 kg BW averaged 226 g in Expt 1 and 272 g in Expt 2.

Those kids in Expt 2 which were completely weaned at 10 kg consumed considerable quantities of concentrates. For growing to 16·9 or 15·7 kg BW, kids in Expt 2 consumed on average either 104 kg milk plus 1 kg concentrates or 34 kg milk plus 15 kg concentrates, respectively.

In Expt 3, consumption of milk and concentrates by kids up to 15 kg BW equalled that of the weaned group in Expt 2 with no significant difference between the two groups of Expt 3. For further doubling their BW, kids of the two groups required either 51 ± 12 or 66 ± 10 days ($P \leqslant 0.05$).

Increasing the proportion of straw from 20 to 40% in complete feeds for the weaned kids in Expt 3 did not significantly affect feed intake but decreased BW gain from 272 to 236 g/day and increased the feed/gain ratio from 4·10 to 5·08 ($P \leqslant 0.05$).

Doubling the proportion of straw in the feed from 20 to 40% caused a decrease in digestibility of total OM from 77 to 59% and of total lipids from 54 to 49%, whereas digestibility of crude fibre was increased from 52 to 55% ($P \leqslant 0.05$) (Table 3). ME, calculated from digestible crude nutrients using Eqn (1), was 14·4 and 11·2 MJ/kg DM in the complete feeds containing 20 and 40% straw, respectively. No comparable information is available for the concentrates fed in Expt 2.

Male kids weighing on average *c*. 22 kg ingested substantially more ME, crude protein and major minerals daily when given complete feeds (both groups of Expt 3) than when fed only on milk (second group of Expt 1), whereas their intake of digestible lipids was less than one fifth of that in milk-fed kids (Table 4).

Kids allowed to grow increased their empty body concentrations of energy. At comparable slaughter weights, energy concentration was higher in kids fed on milk to satiation than in weaned kids owing to higher lipid concentrations in empty bodies of the milk-fed kids ($P \leqslant 0.05$) (Table 5). All kids increased their protein concentration ($P \leqslant 0.05$) in empty body (Table 5) as well as in fat-free empty body (Table 6) compared to newborn kids. In empty bodies of *c*. 24 kg, protein concentrations were higher ($P \leqslant 0.05$) after consuming solid complete feeds (Expt 3) than after consuming milk to satiation (Expt 1).

Empty body concentrations of Ca and P of growing kids never significantly exceeded the concentrations found in newborn kids. In growing kids, concen-

Table 4. *Daily intake of ME, crude protein, digestible lipids and major minerals by German Saanen kids fed on either milk to satiation or complete feeds containing 20 and 40% straw** (*mean* ± S.E., *n* = *4*)

Experiment …	1		3	
Feed …	Milk	Milk	Complete feed	
			20% straw	40% straw
BW (kg) …	3·1–16·8	16·8–26·7	15·3–29·0	15·0–30·3
BW gain (g/day) …	226	240	272	236
Intake (per day)				
ME (MJ)	5·5 ± 0·25	9·2 ± 1·15	14·6 ± 0·45	12·3 ± 0·65
Crude protein (g)	59 ± 2·6	98 ± 11·5	153 ± 4·5	140 ± 7·5
Digestible lipids (g)	67 ± 2·9	113 ± 13·6	24 ± 0·75	21 ± 1·1
Ca (g)	2·6 ± 0·11	4·3 ± 0·55	8·8 ± 0·31	9·7 ± 0·51
P (g)	1·7 ± 0·09	2·9 ± 0·35	4·3 ± 0·14	4·5 ± 0·25
Mg (g)	0·22 ± 0·011	0·36 ± 0·045	2·0 ± 0·04	2·3 ± 0·09
Na (g)	0·55 ± 0·028	0·92 ± 0·111	1·5 ± 0·08	1·6 ± 0·11
K (g)	3·0 ± 0·16	5·0 ± 0·61	5·7 ± 0·21	6·7 ± 0·35

* Calculated from Tables 1, 2 and 3 and ME/GE = 0·96 for milk (Sanz Sampelayo *et al*. 1988).

Table 5. *Weights and chemical composition of empty bodies of German Saanen kids, newborn or fed on milk either to satiation until slaughter (S) or weaned at 10 kg BW (W) (mean ± S.E., expressed on wet weight basis)*

Experiment…	0	1		2		3	
Number of kids…	15	4	4	6	4	4	4
Feeding group…	—	S	S	S	W	W	W
Final age (days)…	—	63	95	52	66	112	133
Final BW (kg)…	3·3	16·8	26·7	16·9	15·7	29·0	30·3
Empty BW (kg)	3·3 ± 0·14	15·1 ± 0·23	24·0 ± 1·87	15·5 ± 0·22	13·0 ± 0·07	24·7 ± 1·31	23·2 ± 0·45
Energy (MJ/kg)	4·5 ± 0·03	10·8 ± 0·38	12·2 ± 0·36	9·9 ± 0·20	7·4 ± 0·24	10·3 ± 0·30	10·4 ± 0·17
DM (g/kg)	225 ± 0·9	383 ± 8·3	416 ± 8·5	356 ± 3·9	296 ± 5·7	389 ± 6·5	388 ± 4·7
Protein (g/kg)	158 ± 1·5	170 ± 2·0	163 ± 2·3	172 ± 1·9	184 ± 2·0	193 ± 3·9	196 ± 1·0
Lipids (g/kg)	12 ± 0·6	164 ± 9·3	206 ± 7·2	142 ± 6·0	71 ± 6·2	146 ± 8·1	146 ± 4·3
Ash (g/kg)	43·4 ± 0·53	42·8 ± 0·48	43·3 ± 1·11	37·7 ± 0·49	38·3 ± 0·75	42·5 ± 1·71	44·0 ± 0·91
Ca (g/kg)	12·6 ± 0·18	12·5 ± 0·16	12·7 ± 0·33	11·0 ± 0·09	10·8 ± 0·21	12·3 ± 0·57	12·6 ± 0·47
P (g/kg)	7·3 ± 0·12	7·7 ± 0·08	7·7 ± 0·22	6·9 ± 0·05	6·8 ± 0·11	7·5 ± 0·27	7·7 ± 0·26
Mg (g/kg)	0·32 ± 0·004	0·43 ± 0·012	0·42 ± 0·016	0·42 ± 0·005	0·38 ± 0·011	0·46 ± 0·023	0·49 ± 0·018
Na (g/kg)	2·00 ± 0·018	1·35 ± 0·029	1·30 ± 0·058	1·52 ± 0·128	1·61 ± 0·086	1·30 ± 0·041	1·30 ± 0·001
K (g/kg)	1·91 ± 0·043	2·08 ± 0·032	2·00 ± 0·001	2·10 ± 0·173	2·38 ± 0·065	1·83 ± 0·032	1·93 ± 0·034

Table 6. *Concentrations of protein, ash and major minerals in fat-free empty bodies of German Saanen kids, newborn or fed on milk either to satiation until slaughter (S) or weaned at 10 kg BW (W) (mean ± S.E., expressed on wet weight basis)*

Experiment…	0	1		2		3	
Number of kids…	15	4	4	6	4	4	4
Feeding groups…	—	S	S	S	W	W	W
Final age (days)…	—	63	95	52	66	112	133
Final BW (kg)…	3·3	16·8	26·7	16·9	15·7	29·0	30·3
Protein (g/kg)	160 ± 1·5	203 ± 1·4	206 ± 4·3	201 ± 1·7	198 ± 2·5	226 ± 4·1	230 ± 0·9
Ash (g/kg)	43·9 ± 0·54	51·1 ± 0·53	54·4 ± 0·92	43·9 ± 0·30	41·2 ± 0·90	49·8 ± 2·04	51·5 ± 1·24
Ca (g/kg)	12·7 ± 0·18	15·0 ± 0·19	15·9 ± 0·29	12·8 ± 0·08	11·6 ± 0·24	14·4 ± 0·73	14·7 ± 0·56
P (g/kg)	7·3 ± 0·12	9·2 ± 0·13	9·6 ± 0·20	8·1 ± 0·04	7·2 ± 0·12	8·7 ± 0·34	9·0 ± 0·32
Mg (g/kg)	0·32 ± 0·006	0·51 ± 0·013	0·53 ± 0·016	0·49 ± 0·003	0·41 ± 0·013	0·54 ± 0·030	0·57 ± 0·021
Na (g/kg)	2·02 ± 0·018	1·62 ± 0·044	1·63 ± 0·060	1·77 ± 0·157	1·74 ± 0·098	1·52 ± 0·038	1·52 ± 0·008
K (g/kg)	1·94 ± 0·039	2·48 ± 0·020	2·52 ± 0·023	2·45 ± 0·201	2·56 ± 0·064	2·14 ± 0·039	2·14 ± 0·021

trations of Mg were always higher and those of Na were always lower than in newborn kids ($P \leqslant 0{\cdot}05$). However, when related to fat-free empty body, kids in Expts 1 and 3 showed significantly higher ($P \leqslant 0{\cdot}05$) concentrations of Ca, P, Mg and significantly lower concentration of Na than newborn kids. Kids in Expt 2, compared to newborn kids, did not show significantly different concentrations of Ca, P, Mg and Na in fat-free empty bodies, but did show a significantly higher K concentration ($P \leqslant 0{\cdot}05$).

DISCUSSION

As empty BW increased from 3 kg at birth to 13–15 kg and 24 kg, concentrations of body energy rose owing to increasing lipid contents (Table 5). This rise was, however, much more pronounced in milk-fed than in weaned kids. Protein concentrations increased with increasing empty BW in weaned kids, although to a lesser extent than lipid concentrations. In kids given milk to satiation, however, no further increase in empty body protein concentration was found above 15 kg. Lower energy concentrations were reported in milk-fed kids weighing up to *c*. 6 kg by Jagusch *et al*. (1983) and Sanz Sampelayo *et al*. (1990) which confirms that energy concentration increases with progressing age and BW.

Male kids fed on a milk replacer for up to 56 days (Schmidely *et al*. 1992) gained 260 g/day in BW and lipid concentration in empty bodies was substantially lower (109 g/kg) than found in this work in milk-fed kids of Expts 1 and 2. The ME intake from milk replacer was 6·9 MJ/day which is *c*. 25% higher than the ME intake of milk-fed kids in Expt 1, and this difference may account for the 15% higher daily BW gain and the lower lipid concentration in the body.

Table 7. *Chemical composition of BW gain in German Saanen kids given only milk to satiation until slaughter* (*Expt 1*), *concentrates ad libitum plus milk either to satiation until slaughter* (*S*) *or in restricted quantities until 10 kg BW* (*R*) (*Expt 2*) *or complete feeds containing 20 or 40% straw* (*Expt 3*)*

Experiment…	1		2		3	
Sex of kids…	Male		Castrate		Male	
Feed…	Milk	Milk	Concentrates+Milk S	Concentrates+Milk R	Complete feed including 20% straw	Complete feed including 40% straw
Initial BW (kg)…	3·1	16·8	3·7	3·8	15·3	15·0
Final BW (kg)…	16·8	26·7	16·9	15·7	29·0	30·3
BW gain (g/d)…	226	240	272	185	272	236
Per kg BW gain						
Empty BW (g)	876	899	894	773	876	706
Energy (MJ)	10·9	13·0	10·4	6·6	11·7	9·8
Protein (g)	152	136	158	150	177	148
Lipids (g)	178	249	163	74	197	164
Ash (g)	37	40	32	28	41	36
Ca (g)	10·9	11·7	9·4	7·8	12·2	10·4
P (g)	6·8	6·9	6·1	5·1	7·2	6·2
Mg (g)	0·40	0·36	0·40	0·31	0·48	0·44
Na (g)	1·0	1·1	1·2	1·1	0·9	0·7
K (g)	1·9	1·7	1·9	2·0	1·1	1·0

* Calculated from Table 5.

Concentrations of energy, protein and lipids in empty bodies weighing 15 kg of kids fed on milk to satiation did not differ significantly ($P \leqslant 0.05$) between intact male kids in Expt 1 and castrated male kids in Expt 2. Castrated kids given solid feeds until they weighed *c.* 30 kg (Pfeffer & Keunecke 1986; Gibb *et al.* 1993) had *c.* 15% lower protein concentrations and *c.* 40% higher fat concentrations in their empty bodies than the male kids in Expt 3. This indicates that a sex effect influencing body composition is relevant only in heavier kids.

No significant influence of the feeding system on empty body mineral concentrations of growing kids could be established. It appears that empty body concentrations of Ca, P and Mg were lower in the castrates in Expt 2 than in the intact male kids in Expts 1 and 3 (Table 5). In castrated or female kids slaughtered between 16 and almost 40 kg, empty body concentrations (g/kg fresh weight) of the three respective elements were 10·8–11·4, 6·2–7·8 and 0·36–0·40 (Pfeffer & Keunecke 1986), which is up to 20% below the values found in this study.

Retention of energy and elements can be calculated by subtracting the product of initial BW and the respective concentration of reference bodies from the respective quantities found in empty bodies at slaughter (Table 7). The newborn kids were taken as reference bodies for the first group of kids in Expt 1 and for both groups in Expt 2. In Expt 1, kids of the first group were reference bodies for the second group. Kids of the group of Expt 2 weaned at 10 kg BW and slaughtered at 15·7 kg BW were used as reference bodies for both groups of Expt 3. This method gives mean retention by groups of animals, but it does not produce meaningful results for individuals. Therefore, composition of BW gain achieved by the respective groups is presented in Table 7 as mean values without standard errors.

Gut-fill as a proportion of BW gain was less in kids fed on milk to satiation than in weaned kids and less in kids given 20% straw than in those given 40% straw complete feeds (Table 5). Energy deposition per kg BW gain rose from 10·9 MJ between birth and 16·8 kg BW to 13·0 MJ between 16·8 and 26·7 kg BW in milk-fed kids of Expt 1 but only from 6·6 MJ between birth and 15·7 kg BW (second group of Expt 2) to 11·7 and 9·8 MJ between 15·7 and *c.* 30 kg (Expt 3), respectively, in kids weaned at 10 kg (Table 7). At the same time, protein deposition fell from *c.* 150 to $<$ 140 g/kg BW gain in milk-fed kids, whereas in weaned kids it remained at *c.* 150 g/kg on 40% straw feeds and rose to $>$ 170 g/kg on 20% straw feeds.

In contrast to energy and protein, no clear effect of age and/or BW on mineral concentration in BW gain can be discerned from the comparison between the two phases of growth. As the influence of sex cannot be excluded, mineral concentrations of weight gain found in the castrates in Expt 2 should not be included in recommendations for intact male kids.

Mineral accretions per kg BW gain of intact male kids may be assumed to be 10·5–12·0 g Ca, 6·3–7·0 g P,

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Table 8. *Estimate of efficiency of utilization of dietary energy by German Saanen kids fed to satiation on either milk or complete solid feeds containing 20 and 40% straw*

Experiment…	1		3	
Feed…	Milk	Milk	Complete feed	
			20% straw	40% straw
BW (kg)…	3·1–16·8	16·8–26·7	15·3–29·0	15·0–30·3
BW gain (g/day)…	226	240	272	236
kJ/kg $BW^{0.75}$ per day				
GE	1034	897	1802	1921
ME	999	860	1395	1157
ME for maintenance	444*	444*	462†	462†
ME for growth (ME_g)	555	416	933	695
Energy retention (ER)	418	318	303	210
ER/ME	0·42	0·37	0·22	0·18
ER/ME_g	0·75	0·76	0·32	0·30

* From Sanz Sampelayo *et al.* (1988).
† From Voicu *et al.* (1993).

0·36–0·49 g Mg, 0·6–1·1 g Na and 0·7–2·0 g K, respectively. These values exceed the respective concentrations of Ca, P and Mg found in gain of growing male lambs by > 30% but show good agreement with lambs with respect to Na and K (Pfeffer & Becker 1982).

In milk-fed kids, mean daily ME intake per unit of metabolic body size ($kg^{0.75}$) was 999 kJ between birth and 16·8 kg BW and 860 kJ above 16·8 kg BW (Table 8). Daily ME intake per $kg^{0.75}$ by ruminating kids consuming complete feeds between 15 and 30 kg BW was 1395 and 1157 kJ, respectively. Ruminating kids consuming 62% more ME did not retain more energy than milk-fed kids. When their ME intake exceeded that of the milk-fed kids by about a third they retained a third less energy. Thus, overall efficiency of utilization of ME was 0·42 and 0·37 in milk-fed kids, but only 0·22 and 0·18 in kids fed on dry complete feeds.

For male kids fed on milk replacer up to 17·5 kg BW, an efficiency of ME utilization of 0·43 can be recalculated from data given by Schmidely *et al.* (1992) which closely fits the value for milk-fed kids presented here. Comparably high efficiency values for utilization of ME have been reported in pre-ruminant calves (Blaxter 1952; Gonzalez-Jimenez & Blaxter 1962; van Es *et al.* 1966; Vermorel *et al.* 1974; Kirchgessner *et al.* 1976) and pre-ruminant lambs (Walker & Norton 1971; Hodge 1974).

Daily ME requirements for maintenance (kJ/$kg^{0.75}$) have been reported to be 444 in milk-fed kids (Sanz Sampelayo *et al.* 1988) and 462 in ruminating kids (Voicu *et al.* 1993). These data agree quite closely, which excludes a substantial difference in maintenance requirements explaining the difference in overall efficiency between milk-fed and ruminating kids.

Subtracting the quoted ME requirements for maintenance from ME intake results in ME for growth (ME_g). Relating energy retention to ME_g results in partial efficiency of utilization of ME_g which was *c.* 0·76 in milk-fed and *c.* 0·31 in ruminating kids. Even if the value for maintenance requirements may leave some concerns in the absolute value, there can be no doubt that efficiency of utilization of ME of milk was higher than that of ME of dry complete feeds.

Efficiency of utilization of ME for growth by milk-fed kids calculated from results of this work corresponds well with findings of Sanz Sampelayo *et al.* (1988), whereas Jagusch *et al.* (1983) found lower values from their results. They analysed empty bodies of two groups of kids, either 2 or 21 days old ranging in BW from 3·3 to 5·3 and from 3·8 to 7·6 kg, respectively. Conclusions in the present work are based on results with less variation within groups and greater differences between groups.

At least part of the difference between kids fed on milk or complete feeds in their efficiency of utilizing ME might be caused by differences in the balance between intake and deposition of lipids. Daily intake of digestible lipids was 67 and 113 g in milk-fed kids of Expt 1 as compared to 24 and 21 g in kids fed on complete feeds of Expt 3, respectively (Table 4). Daily lipid deposition which can be calculated from BW gain (Table 2) and its lipid content (Table 7) was 40 and 60 g in milk-fed kids in Expt 1 compared with 54 and 39 g in ruminating kids in Expt 3, respectively. In milk-fed kids, therefore, net breakdown of digested lipids took place, whereas net synthesis of fat must have occurred in kids fed on complete feeds. Even if all the fat deposited in ruminating kids was synthesised *de novo* at an efficiency of *c.* 0·7 (Armstrong 1969) and deposition of absorbed lipids in milk-fed kids took place at an efficiency of 0·95, this would explain only a very small part of the difference in efficiency of utilization of ME for growth in milk-fed and in ruminating kids.

Webster (1980) showed that total heat increment of feeding (HIF) in sheep fed above maintenance varied between 520 and 612 kJ per MJ ME for barley and fresh herbage, respectively. This variance was totally accounted for by the difference in the contribution of the tissue of the digestive tract, ranging between 192 and 277 kJ per MJ ME, respectively. It may be hypothesised that the high efficiency of utilization of ME observed in milk-fed kids was caused by minimizing the contribution of the digestive tract to HIF during the pre-ruminant phase.

Efficiency of utilization of ME by kids fed on complete feeds in the present work was similar to that observed in lambs fed on diets of chopped hay and pelleted concentrates (Pfeffer *et al*. 1979). A similar efficiency was found for chopped lucerne, but was markedly increased when the same material was ground and pelleted (Thomson & Cammell 1979). ME requirement for maintenance is given as $438 \pm 10{\cdot}9$ kJ/kg $BW^{0{\cdot}75}$ daily. In Table 8, we have adopted the slightly higher value of 462 kJ/kg $BW^{0{\cdot}75}$ daily from Voicu *et al*. (1993). If energy retention is related to ME supply exceeding the assumed requirement for maintenance, efficiency of utilization of ME for growth is calculated which is considerably lower than the values assumed by the AFRC (1997). According to Table 5.6 of AFRC (1997), total ME requirement would be between 15 and 20% lower than the actual ME intake. At present, no explanation for this discrepancy can be given.

From the data shown in Tables 4 and 7, efficiency of utilization of minerals (retention/intake) can be calculated. These efficiency values do not allow for any conclusions to be drawn regarding the availability of minerals from milk or solid feed because they were not determined under conditions that ensured that the animals were operating at a marginal level of intake. Even so, it should be noted that efficiency of utilization of Ca and P from milk by kids reared up to 16·8 kg BW in Expt 1 was 0·88 and 0·78, respectively. Such high values appear impossible in ruminating kids given insufficient Ca or P (Pfeffer *et al*. 1995) or lambs (Boxebeld *et al*. 1983; Wan Zahari *et al*. 1989, 1990). Correspondingly high values have been found for Ca in milk-fed kids (Hines *et al*. 1986) and for Ca and P in pre-ruminant lambs (Walker 1972; Walker & Al-Ali 1987, 1988).

The difference between intake and retention of individual elements must have been excreted either in faeces or in urine. There are three potential reasons for excreting minerals, namely: (i) inevitable (or obligatory) losses, caused by the physiological status of the animal; (ii) unavailability of minerals, caused by the nature of the diet and (iii) adaptive excretions, caused by the degree to which intake of available minerals exceeds the respective quantities required for meeting inevitable losses and retention. Under the conditions of the present experiments it is impossible to differentiate between the three types of excretion of minerals. Therefore, the overall efficiency values for utilization of Ca and P mentioned above must be interpreted as minimum availability values which would result under the unlikely condition of inevitable losses as well as adaptive excretions being zero.

By analogy, the difference between intake and retention must be interpreted as maximum inevitable loss which would result from availability being complete and adaptive excretions being zero. Thus, inevitable daily losses of Ca and P cannot exceed 14 and 16 mg/kg BW, respectively, in milk-fed kids. In ruminating animals, much higher inevitable losses must be assumed which are largely dependent on the quantity of DM ingested (AFRC 1991).

REFERENCES

Agricultural and Food Research Council (1991). Technical Committee on Responses to Nutrients, Report No. 6. A reappraisal of calcium and phosphorus requirements of sheep and cattle. *Nutrition Abstracts and Reviews*, *Series B*, **61**, 573–612.

Agricultural and Food Research Council (1997). Technical Committee on Responses to Nutrients, Report No. 10. The nutrition of goats. *Nutrition Abstracts and Reviews*, *Series B*, **67**, 766–830.

Agricultural Research Council (1965). *The Nutrient Requirements of Farm Animals*. *2*. *Ruminants*. London: Agricultural Research Council.

Armstrong, D. G. (1969). Cell bioenergetics and energy metabolism. In *Handbuch der Tierarnährung* (*Handbook of Animal Nutrition*), *Volume 1* (Eds W. Lenkeit, K. Breirem & E. Crasemann), pp. 385–414. Hamburg and Berlin: Paul Parey.

Blaxter, K. L. (1952). The nutrition of the young Ayrshire calf. 6. The utilization of the energy of whole milk. *British Journal of Nutrition* **6**, 12–19.

Boxebeld, A., Guéguen, L., Hannequart, G. & Durand, M. (1983). Utilization of phosphorus and calcium and mineral maintenance requirement for phosphorus in growing sheep fed a low-phosphorus diet. *Reproduction*, *Nutrition*, *Développement* **23**, 1043–1054.

Gibb, M. J., Cook, J. E. & Treacher, T. T. (1993). Performance of British Saanen, Boer × British Saanen and Anglo-Nubian castrated male kids from 8 weeks to slaughter at 28, 33 or 38 kg live weight. *Animal Production* **57**, 263–271.

Gonzalez-Jimenez, E. & Blaxter, K. L. (1962). The metabolism and thermal regulation of calves in the first month of life. *British Journal of Nutrition* **16**, 199–212.

Hines, T. G., Jacobson, N. L., Beitz, D. C. & Littledike, E. T. (1986). Effects of dietary calcium, vitamin D_3, and corn supplementation on growth performance and mineral

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metabolism in young goats fed whole milk diets. *Journal of Dairy Science* **69**, 2868–2876.

Hodge, R. W. (1974). Efficiency of food conversion and body composition of the preruminant lamb and the young pig. *British Journal of Nutrition* **32**, 113–126.

Jagusch, K. T., Duganzich, D. M., Kidd, G. T. & Church, S. M. (1983). Efficiency of goat milk utilisation by milk-fed kids. *New Zealand Journal of Agricultural Research* **26**, 443–445.

Jarrige, R. (Ed.) (1988). *Alimentation des bovins, ovins et caprins* (*Feeding of Cattle, Sheep and Goats*). Paris: Institut National de la Recherche Agronomique.

Kirchgessner, M. (Ed.) (1995). Zur Energiebewertung beim Wiederkäuer (Energy evaluation in ruminants). *Proceedings of the Society of Nutrition Physiology* **4**, 121–123.

Kirchgessner, M., Müller, H. L. & Neesse, K. R. (1976). Zur partiellen Verwertung der Futterenergie beim Mastkalb (Partial efficiency of utilization of feed energy by the veal calf). *Zeitschrift für Tierphysiologie, Tierernährung und Futtermittelkunde* **37**, 334–337.

Naumann, C. & Bassler, R. (1976). *Die chemische Untersuchung von Futtermitteln. Band III* (*Chemical Analysis of Feeds. Vol. III*). *3rd Edn*. Melsungen: Neumann-Neudamm.

National Research Council (1981). *Nutrient Requirements of Domestic Animals. No. 15: Nutrient Requirements of Goats: Angora, Dairy, and Meat Goats in Temperate and Tropical Countries*. Washington, DC: National Academy Press, National Research Council.

Pfeffer, E. & Becker, K. (1982). Untersuchungen über den Mineralstoff-Ansatz bei wachsenden Lämmern. (Studies of mineral accretion in growing lambs.) *Journal of Animal Physiology and Animal Nutrition* **48**, 107–112.

Pfeffer, E. & Keunecke, R. (1986). Untersuchungen über die Gehalte an Protein, Fett und Mineralstoffen im Körper wachsender Ziegen. (Studies on concentrations of protein, lipids and minerals in growing kids.) *Journal of Animal Physiology and Animal Nutrition* **55**, 166–171.

Pfeffer, E., Becker, K., Prigge, H. & Soller, H. (1979). Untersuchungen an wachsenden Lämmern über den Energiensatz bei Fütterung von Mischfutter mit unterschiedlichen Anteilen von NaOH-behandeltem Stroh. (Studies of energy retention in growing lambs fed diets containing different proportions of NaOH treated straw.) *Zeitschrift für Tierphysiologie, Tierernährung und Futtermittelkunde* **42**, 206–215.

Pfeffer, E., Rodehutscord, M. & Breves, G. (1995). Effects of reducing dietary calcium and/or phosphorus on performance and body composition in male kids. *Journal of Animal Physiology and Animal Nutrition* **74**, 243–252.

Sachs, L. (1984). *Angewandte Statistik* (*Applied Statistics*), *6th Edn*. Berlin: Springer-Verlag.

Sanz Sampelayo, M. R., Munoz, F. J., Guerrero, J. E., Gil Extremera, F. & Goza, J. (1988). Energy metabolism of the Granadina breed goat kid, use of goat milk and a milk replacer. *Journal of Animal Physiology and Animal Nutrition* **59**, 1–9.

Sanz Sampelayo, M. R., Ruiz, I., Gil, F. & Boza, J. (1990). Body composition of goat kids sucking. Voluntary feed intake. *British Journal of Nutrition* **64**, 611–617.

Schmidely, Ph., Bas, P., Rouzeau, A., Hervieu, J. & Morand-Fehr, P. (1992). Influence of trenbolone acetate combined with estradiol-17β on growth performance, body characteristics, and chemical composition of goat kids fed milk and slaughtered at different ages. *Journal of Animal Science* **70**, 3381–3390.

Thomson, D. J. & Cammell, S. B. (1979). The utilization of chopped and pelleted lucerne (*Medicago sativa*) by growing lambs. *British Journal of Nutrition* **41**, 297–310.

van Es, A. J. H., van Weerden, E. J. & Frends, A. M. (1966). Wärmeproduktion, Wasserverdunstung und Energiestoffwechsel bei Mastkälbern, gefüttert mit einem flüssigen Milchersatzfutter (Heat production, water evaporation and energy metabolism in veal calves fed a liquid milk replacer). *Zeitschrift für Tierphysiologie, Tierernährung und Futtermittelkunde* **21**, 25–34.

Vermorel, M., Bouvier, J. C., Thivend, P. & Toullec, R. (1974). Utilisation energétique des aliments d'allaitement par le veau préruminant à l'engrais à differents poids (Utilization of dietary energy by the pre-ruminant calf for growing to different weights). In *Energy Metabolism of Farm Animals* (Eds K. H. Menke, H. J. Lantzsch, & J. R. Reichl), pp. 143–146. Stuttgart: Universität Hohenheim.

Voicu, I., Burlacu, G. H., Criste, R.-D. & Voicu, D. (1993). Study on the energy and protein requirements in goats. *Archives of Animal Nutrition* **44**, 47–61.

Walker, D. M. (1972). Calcium and phosphorus retention by the milk-fed lamb, with estimates of the endogenous losses. *Journal of Agricultural Science, Cambridge* **79**, 171–179.

Walker, D. M. & Al-Ali, S. J. (1987). The endogenous phosphorus excretion of preruminant lambs. *Australian Journal of Agricultural Research* **38**, 1061–1069.

Walker, D. M. & Al-Ali, S. J. (1988). Protein intake and its relationship to urinary calcium excretion in the preruminant lamb. *Australian Journal of Agricultural Research* **39**, 79–85.

Walker, D. M. & Norton, B. W. (1971). Nitrogen balance studies with the milk-fed lamb. 9. Energy and protein requirements for maintenance, live-weight gain and wool growth. *British Journal of Nutrition* **26**, 15–29.

Wan Zahari, M., Thompson, J. K., Scott, D., Topps, J. H., Buchan, W. & Pennie, K. (1989). Effects of growth rate on mineral retention and body composition of growing lambs. *Animal Production* **49**, 443–450.

Wan Zahari, M., Thompson, J. K., Scott, D. & Buchan, W. (1990). The dietary requirements of calcium and phosphorus for growing lambs. *Animal Production* **50**, 301–307.

Webster, A. J. F. (1980). Energy costs of digestion and metabolism in the gut. In *Digestive Physiology and Metabolism in Ruminants* (Eds Y. Ruckebusch & P. Thivend), pp. 469–484. Lancaster: MTP Press Ltd.