The nutrition of the veal calf

3.* A comparison of liquid skim milk with a diet of reconstituted spray-dried skim-milk powder containing 20% margarine fat

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1. Twenty-four bull calves consisting of fifteen Friesians and nine Ayrshires in a randomized block experiment were reared from birth on liquid diets offered *ad lib.* in two feeds daily to a slaughter weight equivalent to 22% of mature cow weight of the breed.

2. The three diets given after the calves had received 7 kg whole colostrum were (*a*) fresh liquid skim milk containing 0·1% butterfat, (*b*) a 'high-fat' diet containing reconstituted spray-dried skim milk and 2·8% margarine fat, and (*c*) the 'high-fat' diet for 14 d from birth followed by liquid skim milk. All calves received supplements of magnesium and iron, and vitamins A, D and E. Digestibility and balance trials were made on nine calves of each breed at both 4 and 10 weeks of age. Certain observations were made at slaughter.

3. Dry-matter and gross energy intakes of calves given the skim-milk diet were greater than for those given the 'high-fat' diet. Daily weight gain, efficiency of food conversion, incidence of a high rectal temperature (> 39·33°), mean rectal temperature and faecal dry-matter content were greater for the calves given the 'high-fat' diet. Age to slaughter and incidence of diarrhoea were much greater for the calves given liquid skim milk.

4. Apparent digestibility of lactose and apparent absorption of ash and calcium were greater with the 'high-fat' diet, but no difference occurred in apparent digestibility of dry matter or protein. Metabolic faecal fat excretion was estimated from the intercept of the relationship between apparently digested fat and fat intake for the calves given the liquid skim-milk diets; the values obtained ranged from 29 mg/kg live weight for Friesian calves at 10 weeks to 49·5 mg/kg for Ayrshire calves at 4 weeks. The true digestibility of the fat was estimated.

5. No difference in Ca or nitrogen retention occurred between diets, but urinary N excretion and N retention/100 g gain in weight were markedly higher and concentration of N in the urine was much lower for calves given the skim milk.

6. Perirenal fat deposition per unit of metabolic body size was 168% greater for calves given the 'high-fat' diet. Kidney weight and skin weight were greater for the calves given the liquid skim-milk diet. The increased kidney weight was related to the very large urine output of the calves given skim milk.

7. In comparison with Ayrshire calves, Friesian calves were much less susceptible to the adverse effects of liquid skim milk, having a lower incidence of diarrhoea and faeces of a higher dry-matter content, but they did have a higher incidence of lung lesions. Friesian calves also had a higher relative growth rate, efficiency of feed conversion, mean body temperature, faecal pH, apparent absorption of Ca, retention of N and Ca per unit of metabolic body size and killing-out percentage, but lower skin weight per unit of metabolic body size. Perirenal fat per unit of metabolic body size did not differ between breeds.

In an earlier experiment (Roy, Stobo, Gaston & Greatorex, 1970) it was shown that an increase in the fat content of a milk diet from 20 to 30% of the dry matter resulted in an increase in fat deposition in the carcass, but no increase in muscle deposition as measured by nitrogen balance. This increase in fat deposition, with no change in N retention, did not result from the fact that the upper limit of N retention had been reached, since with a diet containing 30% fat and 19% protein, N retention was much lower but fat deposition was virtually the same as with a diet containing 30% fat and

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26% protein. It thus appeared that dietary fat was not a readily available source of energy for increasing N retention, at least under fairly optimal environmental conditions.

To confirm this suggestion, an experiment was made to find if nitrogen and calcium retentions were similar for calves given *ad lib.* levels of either liquid skim milk, or skim-milk powder containing, on a dry-matter basis, 20% margarine fat. At the same time it was hoped to find out whether liquid skim milk, when given *ad lib.*, could be used as the sole source of nutrients after the colostrum-feeding period, or whether it was desirable to feed a diet containing a greater amount of fat during the first 14 d of life.

METHODS

Plan of experiment

The experiment, of randomized block design, was done from August 1966 to December 1967 and consisted of three treatments in each of eight blocks of calves. Five blocks consisted of Friesian bull calves, and the remaining three blocks were of Ayrshire bull calves. The calves were removed from their dams before suckling and were placed on experiment within 8 h of birth. The treatments were as follows:

Treatment no.	Colostrum	Diet
1	7 kg whole colostrum	Liquid skim milk *ad lib.*
2	7 kg whole colostrum	Reconstituted spray-dried skim-milk powder containing 20% margarine fat *ad lib.* for 14 d, followed by liquid skim milk *ad lib.*
3	7 kg whole colostrum	Reconstituted spray-dried skim-milk powder containing 20% margarine fat *ad lib.*

Diets

Colostrum. Within 48 h of birth, each calf was given 7 kg whole colostrum obtained from the first two milkings after parturition from Friesian and Ayrshire cows.

Milk. The chemical composition of the diets is given in Table 1. The liquid skim milk contained 9·1% dry matter and 0·1% fat. The 'high-fat' milk diet was reconstituted at the rate of 1 part powder to 6 parts water to give a dry-matter content of 13·7% and a fat content of 2·8%. Both diets were supplemented with similar amounts of vitamins A, D_3 and E, and magnesium per unit of dry matter, but slight differences occurred in concentration owing to difficulties in forecasting the dry-matter content of the liquid skim milk. The 'high-fat' diet, containing non-vitaminized margarine, was prepared in the same manner as diet LFHP used in an earlier experiment and included the antioxidant, butylated hydroxyanisole (Roy *et al.* 1970).

All calves were given 1500 mg iron as iron dextran by injection during the first 3 weeks of life, as described by Roy, Gaston, Shillam, Thompson, Stobo & Greatorex (1964). The gross energy content of the diets, calculated from the calorific values obtained from Andersen (1926), were 4·3 and 5·2 kcal/g for the dry matter of the skim milk and 'high-fat' diets respectively.

Calves

The collection and management of the calves and the records kept were as described by Roy *et al.* (1970).

Digestibility and Ca and N balance trials, consisting of 7 d collection periods beginning at 4 and 10 weeks of age, were made with three replications of each of the two breeds.

The calves were slaughtered when they reached an estimated 22% of mature cow weight for the breed, the live weights being 118 and 136 kg for Ayrshire and Friesian calves respectively (Roy *et al.* 1970). The calves were slaughtered on the Tuesday after the appropriate weight was reached. Weights of carcass, skin, perirenal fat and kidneys were recorded. In addition, the degree of consolidation of tissue in the lungs of the calves at slaughter was assigned a score, to give a measure of respiratory infection. The score ranged from 0 for lungs apparently unaffected to 5 for lungs with the most severe consolidation. The assessment was made by visual appraisal.

Analytical methods

The chemical methods used for analysis of milk, faeces and urine were those described by Roy *et al.* (1964).

Table 1. *Composition of the diets*

	Liquid skim milk	'High-fat' milk substitute
Dry matter (%)	9·07	13·65
Composition of dry matter (%)		
Fat	1·3	20·5
Protein (N × 6·38)	35·9	29·9
Lactose (anhydrous)	53·0	39·5
Ash	8·7	6·6
Calcium	1·3	1·1
Gross energy (kcal/g dry matter)	4·3	5·2
Supplements		
Vitamin A (i.u./kg dry matter)	7497	7250
Vitamin D_3 (i.u./kg dry matter)	1874	1813
Vitamin E (mg/kg dry matter)	22	21
Magnesium (mg/kg dry matter)	257	238
Butylated hydroxyanisole (mg/kg dry matter)	—	32

RESULTS

Mortality. Two calves on treatment 1, and one calf on each of treatments 2 and 3 died. In addition, one Friesian calf on treatment 1 was removed from the experiment at 107 d of age, suffering from severe diarrhoea. Both this calf, and the Ayrshire and Friesian calves on treatment 1 that died at 54 and 70 d of age respectively showed evidence of an *Escherichia coli* localized intestinal infection at post-mortem examination. The Ayrshire calf on treatment 2 that died had a severe pneumonia and an *E. coli* localized intestinal infection at 34 d of age. The Ayrshire calf on treatment 3

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Table 2. *Incidence of diarrhoea, incidence of a high rectal temperature (> 39·33°), mean rectal temperature during the experiment and severity of lung lesions at slaughter for calves given skim milk or a milk containing 2·8% margarine fat*

(Mean values with their standard errors or ranges)

	Treatment no. and diet				Breed		Significance of effect		
	1	2	3						
	Liquid skim milk *ad lib.*	2·8% margarine fat milk for 14 d followed by liquid skim milk *ad lib.*	2·8% margarine fat milk *ad lib.*	SE	Friesian	Ayrshire	Treatment	Breed	Interaction
No. of calves	8	8	8		15	9			
No. of d on which calves had diarrhoea									
(Birth–14 d)	1·3 (range 0–3)	0·1 (range 0–1)	0·1 (range 0–1)		0·1 (range 0–1)	1·2 (range 0–3)	***	***	***
(Birth–slaughter)	19·3 (range 3–77)	12·5 (range 1–42)	1·8 (range 0–7)		3·1 (range 0–8)	24·6 (range 3–77)	**	***	—
No. of d on which calves had a high rectal temperature (> 39·33°)†									
(Birth–14 d)	1·4 (range 0–4)	2·0 (range 0–9)	2·9 (range 0–7)		2·7 (range 0–9)	1·0 (range 0–4)	—	—	—
(Birth–slaughter)	2·1 (range 0–7)	4·0 (range 1–12)	4·6 (range 1–8)		4·3 (range 0–12)	2·4 (range 0–6)	*	—	—
Mean rectal temperature (°C)	39·00	39·06	39·11	0·067	39·11 ± 0·048	38·94 ± 0·062	*	**	—
Incidence of lung lesions at slaughter (%)‡	50·0	50·0	62·5		73·3	22·2	—	***	**
Severity of lung lesions at slaughter (score 0–5)§	1·8 (range 0–5)	1·5 (range 0–4)	1·5 (range 0–4)		2·0 (range 0–4)	0·9 (range 0–5)	—	—	—

* Significant at $P < 0·05$. ** Significant at $P < 0·01$. *** Significant at $P < 0·001$.

† Values (x) transformed to $\sqrt{(x+0·5)}$ before analysis.

‡ Percentages transformed to arcsin √ percentage before analysis.

§ Values transformed by method for ordinal data before analysis.

Table 3. *Effect of liquid skim milk or a milk containing 2·8% margarine fat and the effect of breed on the performance of calves to 22% of mature weight*

(Mean values with their standard errors)

	Treatment no. and diet: 1 Liquid skim milk *ad lib.*	2 2·8% margarine fat milk for 14 d followed by liquid skim milk *ad lib.*	3 2·8% margarine fat milk *ad lib.*	SE	Breed: Friesian	Ayrshire	Significance of effect: Treatment	Breed	Interaction
No. of calves	8	8	8		15	9			
Birth weight (kg)	36·4	36·5	34·3	1·32	39·3 ± 1·46	29·6 ± 1·88	—	**	—
Age to day before slaughter (d)	129	109	101	6·9	102 ± 3·4	131 ± 4·4	—	**	—
Weight gain (kg) (birth to day before slaughter)	91·2	97·0	96·3	1·50	99·9 ± 2·03	94·8 ± 2·62	*	**	—
Total dry-matter intake (kg)	180·6	160·9	132·3	5·73	156·7 ± 4·51	160·0 ± 5·83	***	—	—
Daily dry-matter intake (kg)	1·42	1·50	1·36	0·045	1·54 ± 0·016	1·23 ± 0·020	—	**	—
Relative weight gain (k × 10²)†	1·00	1·24	1·40	0·056	1·30 + 0·029	1·07 ± 0·038	***	**	—
(Adjusted for differences between treatment means for total dry-matter intake)	1·18	1·26	1·20	0·048	1·29 ± 0·026	1·09 ± 0·034	—	***	—
(Adjusted for differences between treatment means for daily dry-matter intake)	1·01	1·16	1·48	0·033	1·18 ± 0·024	1·28 ± 0·031	***	—	—
Feed conversion rate (kg dry matter/kg gain in weight)	1·99	1·67	1·39	0·048	1·57 ± 0·030	1·86 ± 0·038	***	**	—
Total gross energy intake (Mcal) based on total dry-matter intake	780	707	685		718	734			

* Significant at $P < 0·05$. ** Significant at $P < 0·01$. *** Significant at $P < 0·001$.

† $k = \frac{\log_e \text{final weight (kg)} - \log_e \text{birth weight (kg)}}{\text{age (d)}}$.

that died at 2 d of age was probably suffering from haemolytic disease of the newborn (D. C. Ostler, 1967, personal communication).

The deaths of calves on treatments 1 and 2, but not the death that occurred on treatment 3 could certainly be attributed to a treatment effect. However, as the experiment was designed primarily to study the nutritional effects of the diets, all five calves were replaced.

Incidence of diarrhoea (*Table* 2). The incidence of diarrhoea (faeces containing less than approximately 12% dry matter (Roy, Shillam, Thompson & Dawson, 1961)) was much greater for the calves given liquid skim milk. This finding was apparent both during the first 14 d of age, when only calves on treatment 1 received skim milk, and for calves on treatments 1 and 2 during the whole experimental period. Calves given the 'high-fat' diet during the first 14 d (treatment 2) tended to have a lower incidence of diarrhoea from birth to slaughter than those given skim milk during this time, a finding which suggested that the fat was having a beneficial carry-over effect. Ayrshire calves had a much higher incidence of diarrhoea than occurred in the Friesian calves.

Incidence of a high rectal temperature ($> 39.33°$) (*Table* 2). Calves given skim milk had a lower incidence of a high rectal temperature than calves given the 'high-fat' diet. Friesian calves maintained a higher mean rectal temperature than Ayrshire calves throughout the experimental period.

Lung lesions (*Table* 2). Fifty-four per cent of all calves were found to have pneumonia lesions at post-mortem examination. The incidence of lung lesions was much higher for the Friesian than for the Ayrshire calves. The interaction between breed and diet was significant since incidence of lesions was lower for Friesians given liquid skim milk but higher for Ayrshires. There was also a tendency for the Friesian calves to show more severe lesions.

Age at slaughter (*Table* 3). The time taken to reach slaughter weight was greater for the calves given skim milk immediately after the colostrum-feeding period (treatment 1) than for those given the 'high-fat' diet (treatment 3). When liquid skim-milk feeding was delayed until 14 d (treatment 2), the age at slaughter was intermediate between that for the other two treatments, but did not differ from either of them significantly. The age at slaughter was greater for Ayrshire than for Friesian calves.

Dry-matter intake (*Table* 3). Total dry-matter intake from birth to slaughter was much greater for calves given liquid skim milk (treatments 1 and 2) than for those given the 'high-fat' milk (treatment 3). However, mean daily dry-matter intake did not differ between treatments.

The total gross energy intake of the calves given skim milk from birth was much higher than that of calves on the other two treatments. Although there was no difference between breeds in total dry-matter intake, this was largely a reflection of the older age of the Ayrshire calves at slaughter, since the Friesians had a higher daily dry-matter intake.

Relative weight gain (*Table* 3). Relative weight gain was lowest for the calves given liquid skim milk following the colostrum-feeding period; the feeding of the 'high-fat' diet for 14 d after birth had an ameliorating effect in increasing relative weight gain.

This difference between treatments in relative weight gain no longer existed when adjustment was made for differences between treatment means for total dry-matter intake. This was partly to be expected, as adjustment for dry-matter intake was largely an adjustment for differences between treatment means for age at slaughter, but does not take into account the greater calorific value of the dry matter of the 'high-fat' diet. There was a significant difference between treatments but not between breeds when relative weight gain was adjusted for differences in mean daily dry-matter intake. The growth curves of the calves are shown in Fig. 1.

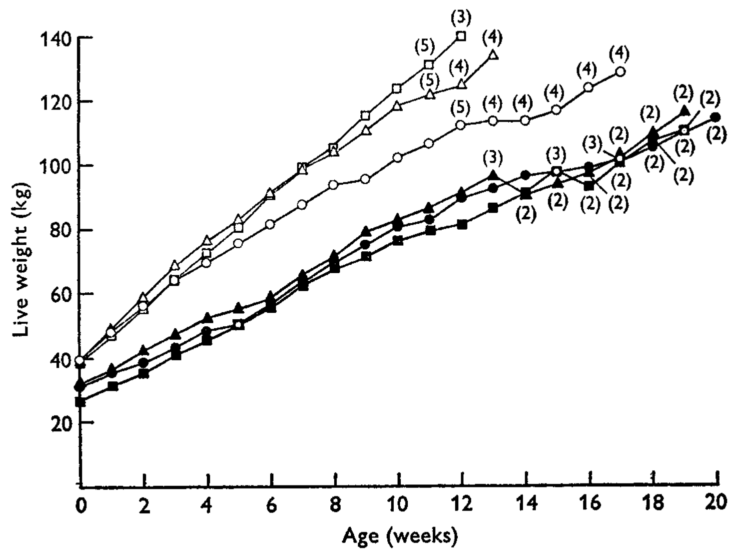

Fig. 1. Effect of liquid skim milk or a milk containing 2·8 % margarine fat on the weight gain of Friesian and Ayrshire calves. ○, △, □, Friesian; ●, ▲, ■, Ayrshire; ○, ●, liquid skim milk *ad lib.*; △, ▲, milk containing 2·8 % margarine fat for 14 d followed by liquid skim milk *ad lib.*; □, ■, milk containing 2·8 % margarine fat *ad lib.* Figures in parentheses are the numbers of calves included in the value.

Feed conversion rate (*Table* 3). The conversion of dry matter into live weight was most efficient for calves given the 'high-fat' diet and least efficient for those given the skim-milk diet after the colostrum-feeding period. The inclusion of fat in the diet for the first 14 d of life had a very marked effect in increasing overall efficiency of conversion.

Efficiency of conversion for the Friesian calves was higher than that for the Ayrshire calves.

Digestibility of the diets and Ca and N balance of the calves

Dry matter (*Table* 4). Dry-matter intake during the collection periods did not differ significantly between treatments, but Friesians, being larger, naturally consumed more than Ayrshires, and intake was also higher at 10 weeks than at 4 weeks of age. However, dry-matter intake in relation to metabolic body-weight ($W^{0.73}$, kg) did not differ with age, but was still significantly greater for the Friesian calves.

Faecal dry-matter content was significantly lower for the calves given liquid skim

Table 4. *Effect of liquid skim milk or a milk containing 2·8% margarine fat, and the effect of breed and age of calf on the apparent digestibility of nutrients*

(Mean values with their standard errors)

	Treatment no. and diet				Breed			Age (weeks)			Significance of effect			
	1 Liquid skim milk *ad lib.*	2 2·8% margarine fat milk for 14 d followed by liquid skim milk *ad lib.*	3 2·8% margarine fat milk *ad lib.*	SE	Friesian	Ayrshire	SE	4	10	SE	Treatment (T)	Breed (B)	Age (A)	Interaction
No. of calves	6	6	6		9	9		18	18					
No. of collection periods	12	12	12		18	18†		18	18†					
Mean live weight (kg)	74·1	85·3	82·2	4·47	95·3	68·5	1·33	62·5	98·6	0·69	—	***	***	BA**
Dry-matter intake/d														TBA*
(g)	1278	1479	1336	80·6	1601	1127	18·9	1182	1546	32·2	—	***	***	—
(g/$W^{0.73}$)	55·4	57·8	54·2	1·60	58·2	53·5	1·07	57·6	54·0	1·54	—	*	—	—
Faecal dry matter (%)	10·0	10·6	14·2	0·86	13·1	10·2	0·70	11·0	12·2	0·38	*	*	—	BA**
Faecal pH	7·6	7·5	7·9	0·14	8·0	7·3	0·10	7·5	7·8	0·08	—	*	*	BA*
Dry matter														
Apparent digestibility (%)	95·2	95·2	95·9	0·45	96·4	94·6	0·56	95·5	95·4	0·21	—	—	—	BA*
Protein														
Apparent digestibility (%)	93·5	93·5	93·7	0·92	94·9	92·2	0·98	93·0	94·1	0·39	—	—	—	BA*
Lactose														
Apparent digestibility (%)	98·2	98·2	99·3	0·24	98·8	98·3	0·10	98·7	98·4	0·12	*	*	—	TA*
Fat														
Apparent digestibility (%)	34·3	25·3	94·6	21·01	82·3	20·4	20·24	49·0	53·7	7·25	—	—	—	—
Faecal fat (g/d)	2·7	3·1	13·2	1·52	5·5	7·2	1·31	5·9	6·8	0·60	***	—	—	—
Estimated true digestibility (%)	96·7	92·3	95·7		98·7	91·0		95·7	94·2					
Ash														
Apparent absorption (%)	85·2	84·1	87·7	1·38	88·0	83·4	1·20	88·2	83·1	0·72	—	—	**	—
Calcium														
Apparent absorption (%)	67·7	63·2	77·7	2·40	77·4	61·6	2·25	77·6	61·4	1·96	**	**	**	—
Retention (g/d)	11·5	12·8	11·2	0·82	15·8	7·9	0·56	11·8	11·9	0·45	—	***	—	BA*
Retention (g/d $W^{0.73}$)	0·51	0·49	0·46	0·026	0·58	0·39	0·028	0·57	0·40	0·028	—	**	**	—

* Significant at $P < 0·05$. ** Significant at $P < 0·01$. ***Significant at $P < 0·001$.
† Includes one value estimated by 'missing-plot' technique (Yates, 1933).

milk, and Ayrshire calves produced faeces of lower dry-matter content than those produced by Friesians. Since faecal dry-matter content tended to decrease with age in the Friesians, but to increase with age in the Ayrshires, there was a significant breed × age interaction.

The low content of dry matter in the faeces of calves given liquid skim milk was associated with a low faecal pH, but the pH did not differ significantly between treatments. However, faecal pH significantly increased with age and was significantly higher for Friesian than for Ayrshire calves. As with faecal dry-matter content, the breed × age interaction for pH was significant.

Apparent digestibility of dry matter did not differ between treatments, breed or age, but the breed × age interaction was significant.

Protein (*Table* 4). Apparent digestibility of protein did not differ between treatments, but once again the breed × age interaction was significant.

The relationships of apparently digested N intake (ADN, g/d) and N intake (NI, g/d) are given in the following equations, together with the residual standard deviations:

Friesian	4 weeks	ADN = 0·974NI–1·71	(SD = 0·500),
	10 weeks	ADN = 0·956NI–0·87	(SD = 1·591),
Ayrshire	4 weeks	ADN = 1·007NI–4·70	(SD = 1·430),
	10 weeks	ADN = 0·977NI–2·13	(SD = 1·020).

Since none of the regression coefficients differed significantly from 1, it could be argued that the true digestibility of protein was approaching 100%. The negative intercept values for the equations can be used as a measure of daily output of metabolic faecal N. The values for Ayrshire calves were 0·49 ± 0·244 and 0·16 ± 0·089 g N/100 g dry matter ingested at 4 and 10 weeks of age respectively, compared with a value of 0·19 g N/100 g dry-matter intake found for Ayrshire calves given whole milk or a milk substitute diet containing 20% fat in the dry matter (Roy *et al.* 1964, 1970). The values for Friesian calves were 0·12 ± 0·105 and 0·05 ± 0·286 g N/100 g dry matter ingested at 4 and 10 weeks of age respectively.

Lactose (*Table* 4). Apparent digestibility of lactose was significantly lower for the calves given liquid skim milk; a significant treatment × age interaction was also apparent for the digestibility of this nutrient.

Fat (*Table* 4). The values for apparent digestibility of the very small amounts of fat in liquid skim milk are meaningless, as it is clear that the majority of the faecal fat produced by calves given this diet was of endogenous origin.

The relationships between apparently digested fat (ADF, g/d) and fat intake (FI, g/d), together with the residual standard deviations for treatments 1 and 2 were as follows:

Friesian	4 weeks	ADF = 1·002FI–2·35	(SD = 0·311),
	10 weeks	ADF = 0·987FI–3·19	(SD = 0·304),
Ayrshire	4 weeks	ADF = 1·005FI–2·56	(SD = 0·781),
	10 weeks	ADF = 0·955FI–2·65	(SD = 0·478).

As the regression coefficients are very close to a value of 1, it could be assumed that the true digestibility of the small amount of butterfat in liquid skim milk was 100%.

The intercepts of these equations indicate values for daily output of metabolic faecal fat per unit of body-weight (kg) as follows:

Friesian	4 weeks	31.7 ± 3.57 mg/kg,
	10 weeks	29.0 ± 2.46 mg/kg,
Ayrshire	4 weeks	49.5 ± 7.50 mg/kg,
	10 weeks	31.5 ± 3.59 mg/kg.

These values for metabolic faecal fat have been used to estimate the true digestibility of the fat, values for which are given in Table 4; these values, especially for the Ayrshires, are considerably lower than might have been expected.

Ash and Ca (*Table* 4). The apparent absorption of ash decreased with age, but treatment and breed were without effect.

Apparent absorption of Ca was lower for calves given the liquid skim milk than for those given the 'high-fat' milk. However, Ca retention, as measured by the differences between intake and faecal loss, did not differ significantly between treatments. Thus, the lower apparent absorption of Ca for the calves given liquid skim milk resulted from a higher Ca intake and a disproportionately higher faecal Ca output.

Friesian calves retained nearly twice as much Ca as did Ayrshires, both in absolute terms and in relation to metabolic body size. Ca retention was similar at 4 and 10 weeks of age, but increased slightly in the Friesian and declined slightly in the Ayrshire calves between 4 and 10 weeks, thus giving a significant breed × age interaction. In relation to metabolic body size, Ca retention declined with age.

N metabolism (*Table* 5). N intake was greater for calves given the skim-milk diet and greater for Friesian than for Ayrshire calves, and increased between 4 and 10 weeks of age.

In spite of these differences in N intake, daily faecal N output did not differ significantly between treatments or breed, although it increased with age, and the breed × age interaction was also significant, since faecal N tended to increase markedly with age for Friesian calves and decrease slightly with age for Ayrshires.

Urinary N output was very much greater for calves given liquid skim milk, greater for Friesians than for Ayrshires and increased markedly with age. Breed × age and treatment × breed × age interactions were also significant.

In spite of the higher urinary excretion of N by the calves given the skim milk, the concentration of N in their urine was very much lower than for the calves given the 'high-fat' milk. This resulted from the fact that weight of urine excreted/unit of metabolic body size ($W^{0.73}$) for calves given liquid skim milk was nearly twice as great as for those given the 'high-fat' milk. The concentration of N in the urine increased with age, but urinary output in relation to metabolic body size was similar at both ages. Friesian calves tended to have a lower concentration of N in their urine and to produce more urine per unit of metabolic body size.

The amount of N retained did not differ between treatments and did not increase with age, but was markedly higher for the Friesian than for the Ayrshire breed. Since the N intake from liquid skim milk was much greater than that from the 'high-fat' milk, the percentage of N intake that was retained was much greater for the latter diet.

Table 5. *Effect of liquid skim milk or a milk containing 2·8% margarine fat, and the effect of breed and age of calf on nitrogen metabolism*

(Mean values with their standard errors)

	Treatment no. and diet				Breed			Age (weeks)			Significance of effect			
	1 Liquid skim milk *ad lib.*	2 2·8% margarine fat milk for 14 d followed by liquid skim milk *ad lib.*	3 2·8% margarine fat milk *ad lib.*	SE	Friesian	Ayrshire	SE	4	10	SE	Treatment (T)	Breed (B)	Age (A)	Interaction
No. of calves	6	6	6		9	9		18	18					
No. of collection periods	12	12†	12		18	18†		18	18†					
Metabolic body size ($W^{0.73}$) (kg)	23·0	25·4	24·7	1·01	27·7	21·1	0·31	20·4	28·4	0·15	—	***	***	BA* TBA*
Live-weight gain/d (kg)	0·51	0·56	0·88	0·086	0·80	0·51	0·072	0·74	0·57	0·056	*	*	—	—
N intake/d (g)	72·5	82·4	62·6	4·55	85·3	59·7	1·37	62·0	83·0	1·61	*	***	***	—
Faecal N/d (g)	4·5	4·8	3·6	0·41	4·4	4·2	0·38	4·0	4·6	0·11	—	—	*	BA**
Weight of urine/d (g/kg $W^{0.73}$)	460	485	258	13·3	425	377	13·3	396	406	16·5	***	—	—	—
N concentration in urine (%)	0·390	0·388	0·490	0·0123	0·396	0·449	0·0139	0·383	0·462	0·0197	***	—	**	BA**
Urinary N/d (g)	41·3	47·2	31·5	2·37	45·1	34·9	1·57	30·4	49·5	1·85	**	*	***	BA* TBA*
N balance/d (g)	26·8	30·5	27·5	2·56	35·9	20·6	1·49	27·6	28·9	1·68	—	**	—	—
(g/kg $W^{0.73}$)	1·17	1·19	1·13	0·080	1·31	1·01	0·081	1·34	0·98	0·076	—	—	*	—
(g/100 g weight gain)	4·51	7·42	3·31	0·901	5·40	4·76	1·003	4·40	5·76	0·944	*	—	—	TBA*
(% of intake retained)	36·4	37·2	43·9	1·51	42·4	36·0	2·03	44·2	34·2	1·96	**	—	*	—
Ratio, N:Ca retention	2·36	2·54	2·51	0·108	2·27	2·67	0·179	2·37	2·57	0·099	—	—	—	—

* Significant at $P < 0.05$. ** Significant at $P < 0.01$. *** Significant at $P < 0.001$.
† Includes one value estimated by 'missing-plot' technique (Yates, 1933).

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Table 6. *Effect of liquid skim milk or a milk containing 2·8% margarine fat and effect of breed on measurements obtained when calves were slaughtered at 22% of mature cow weight*

(Mean values with their standard errors)

	Treatment no. and diet: 1 Liquid skim milk *ad lib.*	2 2·8% margarine fat milk for 14 d followed by liquid skim milk *ad lib.*	3 2·8% margarine fat milk *ad lib.*	SE	Breed: Friesian	Breed: Ayrshire	Significance of effect: Treatment	Breed	Interaction
No. of calves	8	8	8		15	9			
Age at slaughter (d)	130	110	102	6·9	103 ± 3·4	132 ± 4·4	*	**	—
Fasted weight at slaughter (kg) A	118·0	121·6	123·4	2·01	129·7 ± 0·84	106·5 ± 1·09	—	***	—
Dressed carcass weight (kg) B	68·5	70·9	73·2	1·34	78·7 ± 0·61	57·7 ± 0·79	—	***	—
Killing out %, 100 B/A	57·8	57·9	59·1	0·72	60·7 ± 0·54	54·2 ± 0·70	—	***	—
Perirenal fat (kg)	0·43	0·53	1·38	0·113	0·87 ± 0·046	0·63 ± 0·060	***	*	—
(g/kg carcass weight$^{0.73}$)	20	24	59	4·1	36 ± 1·9	32 ± 2·5	***	—	—
Kidneys									
Weight: (kg)	0·66	0·67	0·54	0·025	0·65 ± 0·024	0·57 ± 0·032	**	—	—
As % of carcass weight	0·99	0·97	0·75	0·037	0·84 ± 0·030	1·00 ± 0·039	***	*	—
(g/kg carcass weight$^{0.73}$)	30	30	23	1·1	27 ± 1·0	29 ± 1·2	***	—	—
Skin									
Weight: (kg)	10·0	10·3	9·5	0·32	10·0 ± 0·31	9·9 ± 0·40	—	—	—
(g/kg slaughter weight$^{0.73}$)	309	312	286	8·7	287 ± 8·0	328 ± 10·3	*	*	—

* Significant at $P < 0.05$. ** Significant at $P < 0.01$. *** Significant at $P < 0.001$.

Similarly, the percentage of N intake that was retained, declined with increasing age and tended to be lower for Ayrshire than for Friesian calves.

N retention/100 g weight gain was very much higher for the calves given liquid skim milk and also tended to increase markedly with age. This latter effect may be more a reflection of the tendency for calves to gain weight less rapidly at the older age, especially when wearing a harness for faeces collection, an effect which has been noted previously (Roy *et al.* 1964). The ratio of N retention : Ca retention did not differ between treatments but tended to be higher for Ayrshire calves; this resulted from the abnormally low value of Ca retention by the Ayrshire calves.

Measurements made after slaughter

Fasted weight at slaughter (*Table* 6). No difference in weight at slaughter occurred between treatments, but the weight of the Friesian calves was, as determined by the design of the experiment, higher than that of the Ayrshire calves.

Carcass measurements (*Table* 6). Carcass weight and killing-out percentage did not differ between treatments but were greater for the Friesian than for the Ayrshire breed. The absolute weight of perirenal fat and the weight of this fat in relation to metabolic body size was between two- and three-fold greater for calves given the 'high-fat' milk. Although the absolute weight of perirenal fat was greater for the Friesian breed, no difference between breeds was apparent when weight of fat was related to metabolic body size.

Absolute kidney weight and kidney weight in relation either to carcass weight or to carcass weight$^{0.73}$ was much greater for calves given the liquid skim milk. Although there was a breed difference in kidney weight expressed as a percentage of carcass weight, this difference was no longer apparent when the comparison was made on the basis of carcass weight$^{0.73}$.

Absolute skin weight did not differ between diets or breeds but, in relation to metabolic body size, skin weight was heavier in the calves given skim milk and was heavier for Ayrshire than for Friesian calves.

DISCUSSION

The findings of this experiment show that a greater intake of dry matter and energy from liquid skim milk containing 1% fat in the dry matter is necessary to achieve similar slaughter weights to those obtained from a milk substitute containing 20% fat in the dry matter.

The results confirm the view expressed earlier in the paper that fat in milk substitute diets does not provide a readily available source of energy that can be utilized to bring about an increase in N retention, even when energy intake rather than protein intake is the limiting factor for growth. Thus, in the balance trials, there was no difference between treatments in dry-matter intake and, although energy intake was therefore lower for calves given the skim milk, N retention and Ca retention were very similar for both diets.

The higher growth rate achieved by the calves given the 'high-fat' diet, which resulted in a shorter time to reach the prescribed slaughter weight, could be attributed partly to the greater fat deposition in the carcass, as demonstrated by the increased weight of perirenal fat. An estimate of the total weight of fat in the carcass of calves given the 'high-fat' milk may be made by the method used in the experiment reported previously (Roy *et al.* 1970). The resultant value of 5·77 kg fat, equivalent to 7·9% of carcass weight at a live weight of 123 kg, compares with a corresponding value of 10·3% of carcass weight at a live weight of 110 kg for veal calves given the same diet (LFHP) in the earlier work (Roy *et al.* 1970). The reason for the difference between experiments is not clear, but it may be a reflection of the higher incidence of subclinical infection with *E. coli* due to feeding diets that predisposed to diarrhoea in the present experiment.

In addition to the markedly lower fat deposition in the carcass, the slower growth rate of the calves given skim milk was clearly associated with the inefficient use of the digested energy, as reflected in the poorer conversion rates, shown by these calves. It is known that excess protein is deaminated, with a consequent loss of energy in the urine. In the present experiment, calves given skim milk excreted 40% more N in their urine, of which about 83% would be expected to be in the form of urea (Blaxter & Wood, 1951), thus entailing an inevitable loss of 5·45 kcal/g N. In addition, energy intake in the form of protein results in an increase in heat production and is thus utilized less efficiently than energy supplied as either carbohydrate or fat (Blaxter, 1962).

The small amount of butterfat that was present in skim milk was digested as efficiently as that in the 'high-fat' milk diet, after making allowances for metabolic faecal fat excretion. The estimated endogenous faecal fat values varying from 29 to 50 mg/kg may be compared with three values obtained with calves given a fat-free synthetic diet at 2 weeks of age by Cunningham & Loosli (1954), namely 29, 19 and 26 mg/kg live weight or 1·5, 0·8 and 1·4 g fat/d. The estimated true digestibility of fat indicated a decline with age, which is in contrast to the generally accepted view that the apparent digestibility of fat increases with age, especially with fats of low apparent digestibility (Roy *et al.* 1961; Roy, Stobo & Gaston, 1963). Since the digestibility of protein did not suffer significantly between treatments and that of lactose was only slightly lower on the skim-milk diet, differences in digestibility did not appear to be an important factor in the lower utilization of skim milk, in spite of the very much looser faeces and the higher incidence of diarrhoea that occurred with calves given the skim-milk diet. The only obvious effect on digestibility was in the reduction in the percentage absorption of Ca. However, the amount of Ca retained was unaffected by diet, the lower percentage absorption that occurred being the result of a much higher Ca intake and proportionately greater faecal losses from the calves given skim milk.

The lower mean body temperature and the tendency for a lower incidence of a high rectal temperature for the calves given the skim-milk diet suggests a higher heat loss than occurred when the 'high-fat' diet was given. This may have been asssociated with a reduced subcutaneous fat layer in the former calves, which was not completely counterbalanced by the increase in skin weight that occurred. The greater output of water in the urine and faeces of calves given skim milk must also have contributed considerably to their heat loss.

It is probable that the heavier kidneys of the calves given skim milk resulted from the very large amount of urine they excreted, which was almost double that excreted by calves given the 'high-fat' milk. Although the calves given skim milk excreted considerably more N in the urine, the concentration of urinary N was considerably less than for those given the 'high-fat' diet. There was a highly significant relationship ($P < 0.001$) between urine output per unit of metabolic body size at 10 weeks of age and kidney weight/carcass weight$^{0.73}$, the regression equation, with the residual standard deviation, being as follows:

$$Y = 0.0275x + 17.8 \quad (\text{SD} = 3.18),$$

where Y = kidney weight/carcass weight$^{0.73}$ (g) and x = daily urinary excretion/live weight$^{0.73}$ at 10 weeks of age (g).

The intake of water for the calves given liquid skim milk which had a low dry-matter content was considerably higher than for calves given the 'high-fat' diet. The difference between daily intake of water and losses in urine and faeces, together with N retention/100 g weight gain, at 10 weeks of age are given below:

		Water (kg)				
Treatment	Diet	Intake	Faeces	Urine	Intake − (faeces + urine)	N retention (g/100 g weight gain)
1	Skim milk	14.4	0.6	12.1	1.7	5.07
2	Skim milk	17.0	0.7	14.3	2.1	3.86
3	'High-fat' milk	9.4	0.3	7.1	2.0	4.05

In this computation, a dry-matter content of urine of 2.6% was assumed, based on a specific gravity of 1.010 and the use of Lang's coefficient (Hawk, Oser & Summerson, 1954).

If the same loss of water by vapourization from the lungs and skin occurred for calves on each of the three treatments, it would appear that the poor performance of calves on treatment 1 given skim milk may have resulted from a lower level of hydration of the tissues. This could account in part for the very high deposition of N/100 g weight gain for these calves and also for their greater susceptibility to dehydration. Mathieu & Barré (1964), using milk diets containing from 5 to 45 g fat/kg milk, found increasing N retention/kg gain in weight as the fat content in the diet was reduced, and also increased urine production with diets of low fat content.

The difference between the Friesian and Ayrshire breeds was shown in several ways. Firstly, the Friesian calves given liquid skim milk were much less susceptible to diarrhoea during the first 14 d of life. Converse (1949) similarly found that Friesian calves were much easier to rear on a skim-milk diet directly after the colostrum-feeding period than Jersey calves. This lower susceptibility to diarrhoea was evident throughout our experiment; in particular the Friesian calves produced faeces of a higher dry-matter content and higher pH than the Ayrshire calves at both 4 and 10 weeks of age. Even when given the 'high-fat' diet, Friesian calves still maintained a higher faecal dry-matter content. However, Friesian calves had a higher incidence of lung lesions, a finding in keeping with results from more recent experiments (J. H. B. Roy & I. J. F. Stobo, 1970, unpublished).

The overall relationship ($P < 0{\cdot}001$) between the faecal dry-matter content and faecal pH, together with the residual standard deviation, was:

$$Y = 3{\cdot}47x - 14{\cdot}97 \quad (\text{SD} = 2{\cdot}95),$$

where Y = dry matter content of faeces (%) and x = pH of faeces.

Secondly, the Friesian calves retained very much more N and Ca, both in absolute terms and per unit of metabolic body size. The greater N retention was expected in view of the results of earlier work (Roy, Stobo & Gaston, 1965; Roy, 1967) during which it was also found that the ratio of N:Ca retention was much higher for the Friesian breed. In that experiment, Ca retention/$W^{0{\cdot}73}$ did not differ between breeds, whereas in the present experiment Ca retention/$W^{0{\cdot}73}$ was much lower for the Ayrshire calves, and thus the ratio of N:Ca retention tended to be higher for this breed. It is probable that the low Ca retention of the Ayrshire calves in the present experiment was due to the high faecal Ca loss associated with faeces of low dry-matter content (Blaxter & Wood, 1953).

Thirdly, the greater skin weight in relation to metabolic body size of Ayrshire calves has been noted previously (Roy, Stobo & Gaston, 1966). The greater weight of kidneys in relation to carcass weight for the Friesian breed was probably due to kidney weight being more closely related to metabolic body size than to body-weight (Brody, 1945); this was indicated by the finding that kidney weight/carcass weight$^{0{\cdot}73}$ did not differ between breeds. Similarly, perirenal fat deposition/carcass weight$^{0{\cdot}73}$ did not differ between breeds at the same stage of maturity, which confirms our earlier findings (Roy *et al.* 1966).

Fourthly, the higher mean body temperature of Friesian calves, compared with Ayrshire calves, given liquid diets *ad lib.* has also been noted previously (J. H. B. Roy, I. J. F. Stobo & H. J. Gaston, unpublished).

The results of this experiment confirm the finding of an earlier experiment that absolute N retention remains approximately constant irrespective of age in calves given liquid diets *ad lib.* (Roy *et al.* 1964) although the maximum level of N retention attained appears to vary between breeds.

Apparent absorption of Ca from the 'high-fat' milk containing margarine was considerably lower than when whole milk was fed in an earlier experiment (Roy *et al.* 1964). In that experiment, apparent absorption of Ca by Ayrshire calves fell from 93% at 4 weeks to 83% at 10 weeks. In the present experiment, the corresponding values were 77% and 60% for Ayrshire calves and 94% and 79% for Friesians.

For a number of variables studied, there was a significant breed × age interaction. Dry-matter content of faeces, faecal pH and apparent digestibility of dry matter and protein declined with age for the Friesian but increased for the Ayrshire, whereas daily faecal N output showed the opposite trend. A breed × age interaction also occurred for urinary N excretion and for N concentration in the urine, which increased with age to a much greater extent for the Ayrshire calves.

The only significant treatment × age interaction was for apparent digestibility of lactose, for which digestibility increased with age for calves given liquid skim milk after the colostrum-feeding period but declined with age for those given liquid skim milk from 14 d of age or the 'high-fat' diet. This finding possibly might have been the result of adaptation at a young age to the diet with a high lactose content. Such adaptation, by an increase in intestinal lactase production has been found in calves given whole milk supplemented with 15% lactose (Huber, Rifkin & Keith, 1964).

In conclusion, it is clear that the beneficial effect of fat in a milk diet is twofold. First, its inclusion increases the dry-matter content of the faeces, possibly as a result of reducing the concentration of protein or soluble carbohydrate in the diet (Roy, 1969). Secondly, it results in greater deposition of fat in the carcass. However, under our experimental conditions the fat is not a readily available source of energy for increasing muscle deposition or bone growth, with the result that the same N and Ca retention can be obtained whether the milk contains 20% or 1% fat on a dry-matter basis.

From a practical viewpoint, skim milk is not a suitable diet for feeding to calves as the sole source of nutrients, owing to the waste of protein involved, and because of its tendency to cause diarrhoea, particularly during the first 14 d of life.

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