The nutrition of the veal calf

2.* The effect of different levels of protein and fat in milk substitute diets

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1. Seventy-two bull calves, comprising forty-eight Ayrshire and twelve each of the Friesian and Jersey breeds, were used in a randomized block experiment. They were reared from birth on liquid diets, offered in two feeds daily, at either restricted or *ad lib.* levels. The restricted level of feeding was such that sufficient diet was fed to allow for a weight gain of 1 kg/d, and the calves given this level of feeding were slaughtered at a weight 77 kg above the mean birth weight of the breed. The calves given the diets *ad lib.* were slaughtered at 22 % of mature cow weight of the breed.

2. Three milk substitutes, based on spray-dried skim-milk powder, spray-dried whey powder and margarine fat, were compared. Two of these were high-protein diets (26–29 % protein) designed to contain either 20 % fat (LFHP) or 30 % fat (HFHP) and the other was a low-protein diet (19 % protein) designed to contain 30 % fat (HFLP).

3. Age at slaughter was lowest for diet HFHP and highest for diet HFLP. Total dry-matter intake did not differ between treatments, but daily dry-matter intake was lower on diet HFLP. Relative weight gain did not differ between diets LFHP and HFHP but was much greater than that for diet HFLP. After adjustment for differences between treatments in mean daily dry-matter intake, relative weight gain tended to be highest for diet HFHP. No difference occurred between treatments in the incidence of diarrhoea and of a high rectal temperature ($> 39{\cdot}33°$). However, mean rectal temperature was higher for calves given the HFHP diet than for those given the HFLP diet.

4. Digestibility and nitrogen and calcium balance trials were made on six of the replications of Ayrshire calves at 4 and 10 weeks of age. Dry-matter intake at 10 weeks of age was lower for calves given diet HFLP than for those given the other diets. Apparent digestibility of fat tended to be lower for the HFLP diet. True digestibility of protein did not differ significantly between treatments. Apparent digestibility of lactose was highest for the HFLP diet.

5. No difference occurred between the two high-protein diets (LFHP and HFHP) in N or Ca retention, but N and Ca retention by calves on the low-protein diet (HFLP) was markedly lower. Daily faecal N excretion was unaffected by treatment, but daily urinary N excretion was lower and the biological value of the protein was higher for diet HFLP than for diet LFHP, with the corresponding values for diet HFHP being intermediate between the two. N retention/100 g weight gain was lower on diet HFLP, lower at 4 weeks of age than at 10 weeks, and lower at the restricted than at the *ad lib.* level of feeding at 4 weeks of age. Metabolic faecal N and endogenous urinary N at 4 weeks of age were estimated as 0·192 g/100 g dry-matter intake and 192·9 mg/kg$^{0{\cdot}73}$ live weight respectively.

6. Haematological findings showed that the high-fat diets (HFHP and HFLP) resulted in a slower rate of decline in packed cell volume and haemoglobin content with age. The low-protein diet (HFLP) resulted in a lower rate of increase with age in the percentage of lymphocytes. Diet HFHP resulted in a decline with age in the percentage of eosinophils compared to a marked rise with the other two treatments.

7. Carcass weight did not differ between treatments, but perirenal fat deposition was much higher for the calves given the high-fat diets (HFLP and HFHP).

8. It is concluded that dietary fat is not a readily available source of energy for increasing N retention in calves given large quantities of milk substitutes, based on milk products with added fat. Unless additional fat deposition in the carcass is required, no advantages in weight

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gain accrues from increasing the fat content of a milk substitute diet above 20%. A milk substitute diet containing only 19% protein (20% of digestible energy as protein) contains insufficient protein to support maximum weight gain.

In an earlier experiment (Roy, Gaston, Shillam, Thompson, Stobo & Greatorex, 1964) the amount of nitrogen retained daily by Ayrshire calves, given whole milk at almost *ad lib.* levels, did not increase with age, similar amounts being retained at 4, 7 and 10 weeks of age. Since the daily intake of N increased with age, the percentage utilization of dietary N declined as the calves grew older.

This decline in the utilization of dietary N with increasing age could have resulted from a dietary deficiency of energy in relation to protein after 4 weeks of age. Alternatively, the level of maximum protein deposition may have been reached at 4 weeks of age, so that additional dietary energy would probably result only in increased fat deposition with little or no change in N retention.

To obtain further information on the effect of increasing the energy content of a milk substitute diet on N retention in veal calves, a comparison was made of two diets, one designed to contain 20% and the other 30% fat. In addition, a comparison was made with a diet containing a much lower content of protein together with 30% fat. The diets were fed either in restricted amounts, calculated to produce a weight gain of 1 kg/d, or at *ad lib.* levels.

METHODS

Plan of experiment

The experiment, of randomized block design, was done with seventy-two bull calves from September 1964 to March 1966 and consisted of six treatments in each of twelve blocks. Eight blocks were of the Ayrshire breed and two blocks each of the Jersey and Friesian breeds. 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	Milk substitute	Level of feeding
1	7 kg whole colostrum	20% fat, high-protein diet (LFHP)	Restricted
2			*ad lib.*
3		30% fat, high-protein diet (HFHP)	Restricted
4			*ad lib.*
5		30% fat, low-protein diet (HFLP)	Restricted
6			*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 of Friesian, Ayrshire and Jersey cows.

Milk substitute. The chemical composition of the diets is given in Table 1. The two high-protein diets (LFHP and HFHP) were prepared by homogenizing the appropriate quantity (20 and 30% respectively) of non-vitaminized margarine, having the fatty acid composition shown in Table 1 (as used by Roy, Shillam, Thompson & Dawson (1961)) into liquid skim milk, which was preheated at a low temperature before spray-drying to prevent denaturation of the whey proteins (Shillam, Dawson & Roy, 1960; Shillam, Roy & Ingram, 1962*a–c*; Shillam & Roy, 1963*a–c*; Tagari & Roy, 1969). The low-protein diet (HFLP) was prepared by mixing a similar milk powder containing 40% margarine with spray-dried whey powder in the ratio of 7:3 parts by weight. All three diets were reconstituted at the rate of 1 part powder to 6 parts water to give a dietary dry-matter content of 13·7%.

The diets were supplemented with vitamins A, D_3 and E and $MgCl_2.6H_2O$, and with the antioxidant, butylated hydroxyanisole, as shown in Table 1. All calves were given a total supplement of 1500 mg iron in the form of 5 ml iron dextran, containing 100 mg Fe/ml (Imposil 200; Fisons Pharmaceuticals Ltd) injected intramuscularly on the 7th, 14th and 21st d of age, as described by Roy *et al.* (1964).

The gross energy contents of the diets calculated from the calorific values of fat, protein and lactose as given by Andersen (1926) were 5·2, 5·6 and 5·4 kcal/g dry matter for diets LFHP, HFHP and HFLP respectively.

Table 1. *Composition of the milk substitute diets*

Treatment no.	1 and 2	3 and 4	5 and 6
Diet	LFHP	HFHP	HFLP
Dry matter (%)	95·5	95·9	95·4
Composition of dry matter (%)			
Fat	20·8	29·2	27·5
Crude protein (N × 6·38)	29·4	26·3	19·3
Lactose (anhydrous)	40·0	35·9	44·6
Ash	6·7	5·9	6·7
Calcium	1·1	1·0	0·9
Non-casein N as % total N	18·4	17·8	—*
Gross energy (kcal/g dry matter)	5·2	5·6	5·4
Supplements			
Vitamin A (i.u./kg)	7330	7300	7350
Vitamin D_3 (i.u./kg)	1830	1820	1840
Vitamin E (mg/kg)	21	21	21
Magnesium (mg/kg)	262	261	262
Butylated hydroxyanisole (mg/kg)	32	45	42

* Value affected by presence of whey powder.

Fatty acid composition (% total fatty acids) of non-vitaminized margarine

Butyric	(4:0)	2·2
Isovaleric	(5:0)	0·6
Caproic	(6:0)	Trace
Caprylic	(8:0)	2·6
Capric	(10:0)	2·1
Lauric	(12:0)	17·9
Myristic	(14:0)	7·3
Palmitic	(16:0)	18·3
Palmitoleic	(16:1)	0·5
Stearic	(18:0)	4·5
Oleic	(18:1)	35·6
Linoleic	(18:2)	8·4

Calves

The collection and management of the calves were as described by Roy *et al.* (1964), except that the calves were housed under controlled environmental conditions in galvanized metal pens having galvanized expanded metal floors. The calves were fed twice daily at 08.15 and 17.00 h, the diets being hand-fed or automatically dispensed into polyethylene buckets (Roy, Stobo & Gaston, 1965).

The amount of milk offered to calves fed at the restricted level, which was designed to produce a live-weight gain of 1 kg/d, was calculated on the basis that diet LFHP had a calorific value of 4·97 kcal digestible energy/g dry matter, an assumption that was later confirmed in this experiment. The maintenance requirement of a calf was assumed to be 52·4 kcal digestible energy/kg live weight (Blaxter & Wood, 1951), and the production requirement 3020 kcal digestible energy/kg weight gain (Roy *et al.* 1964). Diets HFHP and HFLP were fed at the same rates as diet LFHP. When given at the restricted level, the amounts offered, based on live weight, were adjusted at weekly intervals.

The records kept were the same as those described by Roy *et al.* (1964). Blood samples were taken from the jugular vein of all calves before their first feed and on the day before slaughter for haematological measurements.

Digestibility and N and calcium balance trials were made with six replications of Ayrshire calves at 4 and 10 weeks of age by the methods of Roy *et al.* (1964). For estimation of Ca retention, the very small losses of Ca in the urine were ignored (Blaxter & Wood, 1952). The collection periods were of 7 days duration, beginning after the morning feed when the appropriate age was reached. The calves on the treatments in which the diet was restricted were slaughtered when the calves reached a weight corresponding to 77 kg above the mean birth weight of the breed; those on the *ad lib.* régime were slaughtered at 22% of mature cow weight of the breed, based on the 10-year average weight of old and young cow classes (excluding heifers) exhibited at the London Dairy Show from 1950 to 1960 (Foot & Roy, 1967). The slaughter weights (kg) are given below:

	Restricted	*ad lib.*
Jersey	105	90
Ayrshire	111	118
Friesian	118	136

The calves were slaughtered on the Tuesday after the appropriate weight was reached. The weights of carcass and perirenal fat were recorded.

Analytical and haematological methods

The analytical methods used for milk, faeces and urine and the haematological methods used were those described by Roy *et al.* (1964).

Statistical analysis

The transformations of certain values before analyses were as described by Roy *et al.* (1964).

RESULTS

Performance from birth to slaughter

Mortality. In treatments 1 and 2 (LFHP) seven calves were replaced. Two calves, one Ayrshire and one Jersey, died from an *Escherichia coli* localized intestinal infection at 6 and 10 d of age respectively, and one other Jersey calf died as a result of diarrhoea at 53 d of age. Two Ayrshire calves were rejected as they refused to suck colostrum, one Ayrshire was rejected at 28 d of age as a result of weak legs, and one Ayrshire was replaced as it weighed only 71 kg at 20 weeks. In treatments 3 and 4 (HFHP), five Ayrshire calves were replaced. One was slaughtered at 12 weeks of age with severe pasteurella pneumonia, three were replaced as a result of very low weight gains, namely 11 and 8 kg in 8 weeks, and 12 kg in 14 weeks, and the remaining calf was replaced as it did not gain any weight from 91 to 130 d of age. No calves were replaced in treatments 5 and 6 (HFLP).

Performance (*Table* 2). Since there were no marked differences between the results for the calves given the diets at restricted or *ad lib.* levels, and since the diet × level of feeding interaction was in all instances non-significant, the results for each main treatment effect were combined. There were no significant differences between treatments in birth weight, total dry-matter intake or final live weight, but mean daily dry-matter intake and relative weight gain (k) were significantly lower for the calves given the low-protein diet (HFLP). Age at slaughter and feed conversion rate were lowest for diet HFHP and highest for diet HFLP. Relative growth rate did not differ between the two high-protein diets (LFHP and HFHP) but was significantly higher than that for calves given the low-protein diet (HFLP). After adjustment for differences between treatments in mean birth weight and daily dry-matter intake, relative weight gain did not differ between treatments, but tended to be highest for the diet containing the most energy (HFHP).

Incidence of diarrhoea and of a high rectal temperature (*Table* 2). No difference in incidence of diarrhoea or of a high rectal temperature ($> 39{\cdot}33°$) occurred between treatments during the first 14 d of life or during the whole experimental period.

Mean rectal temperature (*Table* 2). Mean rectal temperature was significantly higher for calves given the HFHP diet than for those given the HFLP diet.

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

Digestibility (*Table* 3). At both 4 and 10 weeks of age the mean live weight of calves in treatments 5 and 6 (HFLP) was significantly lower than that of calves given the other two diets. This finding was reflected in a lower intake of dry matter for calves given diet HFLP at 10 weeks of age.

Apparent digestibility of fat tended to be lower for calves given the HFLP diet at both 4 and 10 weeks of age but the differences were not significant. Apparent digestibility of protein was lower for calves given the HFLP diet at both 4 and 10 weeks of age, but only significantly so at 10 weeks of age. On the other hand, apparent digestibility of lactose was significantly lower for the calves given the diet of low fat content (LFHP), although values for all treatments were greater than 99%.

The digestible energy contents, calculated from the digestibility of the various nutrients of the three diets, were 5·0, 5·4 and 5·1 kcal/g dry matter, whilst the proportions of this energy attributable to protein were 33, 27 and 20% for diets LFHP, HFHP and HFLP respectively.

Ca retention (*Table* 3). Absolute retention of Ca and retention per unit of metabolic body size ($W^{0{\cdot}73}$) was significantly lower for the calves given the low-protein diet (HFLP) than for those given the other two diets.

Table 2. *Effect of the fat and protein content of milk substitute diets on the performance of calves*

(Mean values with their standard errors or ranges)

	Treatment no. and details			Pooled SE of mean	Significance of difference between treatments	
	1+2 LFHP	3+4 HFHP	5+6 HFLP		1+2 *v.* 5+6	3+4 *v.* 5+6
No. of calves	24	24	24			
Birth weight (kg)	33·6	34·7	33·6	0·73	—	—
Dry-matter intake (kg)						
Total	116·0	112·1	118·8	2·93	—	—
Mean daily	1·23	1·22	1·12	0·026	**	**
Final live weight (kg)	115·6	116·8	111·5	1·74	—	—
Age at slaughter (d)	99	95	111	3·9	*	**
Relative weight gain (k × 10²)†	1·33	1·34	1·16	0·043	**	**
Adjusted relative weight gain (k × 10²)†‡	1·26	1·32	1·25	0·031	—	—
Feed conversion rate (kg dry matter/kg weight gain)	1·43	1·38	1·54	0·039	*	**
No. of d on which calves had diarrhoea§						
(Birth–14 d)	0·7 (range 0–4)	1·1 (range 0–4)	1·5 (range 0–6)	—	—	—
(Birth–slaughter)	3·9 (range 0–26)	3·3 (range 0–16)	2·7 (range 0–12)	—	—	—
No of d on which calves had a high rectal temperature (> 39·33°)§						
(Birth–14 d)	2·1 (range 0–6)	3·0 (range 0–11)	2·5 (range 0–8)	—	—	—
(Birth–slaughter)	3·7 (range 0–11)	4·9 (range 0–17)	4·5 (range 0–10)	—	—	—
Mean rectal temperature (°C) (birth–slaughter)	39·06	39·11	39·00	0·025	—	**

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

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

‡ Adjusted for differences between treatments in mean birth weight and dry-matter intake/d.

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

Table 3. *Effect of the fat and protein content of milk substitute diets on the digestibility of their constituents by calves*

(Mean values with their standard errors)

	At 4 weeks of age					At 10 weeks of age				
	Treatment no. and details					Treatment no. and details				
	1+2 LFHP	3+4 HFHP	5+6 HFLP	Pooled SE of mean	Significance of difference between treatments	1+2 LFHP	3+4 HFHP	5+6 HFLP	Pooled SE of mean	Significance of difference between treatments
No. of calves	12	12	12			12	12	12		
Live weight (kg)	58·7	61·6	53·4	2·18	*	96·1	101·1	84·7	3·66	*
Mean age (d)	33	33	33	0·9	—	77	74	75	1·3	—
Dry-matter intake (g/d)	1069	1069	997	48·7	—	1389	1410	1109	80·3	*
Faecal dry matter (%)	15·9	17·9	16·5	0·89	—	16·0	16·1	15·6	0·92	—
Apparent digestibility (%)										
Dry matter	96·6	96·4	95·8	0·63	—	95·6	95·9	95·0	0·57	—
Fat	95·6	95·5	92·7	1·40	—	94·0	94·6	92·0	1·22	—
Lactose	99·2	99·6	99·9	0·16	*	99·1	99·6	99·8	0·18	*
Protein	94·4	93·5	91·8	0·90	—	93·9	93·7	90·0	0·87	**
True digestibility (%)										
Protein	98·6	98·2	98·1	0·91	—	98·2	98·3	96·3	0·89	—
Apparent absorption (%)										
Ash	90·8	91·4	91·0	1·68	—	83·5	87·8	87·6	1·66	—
Calcium	85·2	88·2	84·1	2·99	—	71·8	82·1	75·9	3·32	—
Calcium retention										
(g/d)	10·4	9·7	7·8	0·49	**	11·5	12·1	8·0	0·87	**
(g/kg$^{0·73}$ d)	0·5	0·5	0·4	0·02	**	0·4	0·4	0·3	0·03	*

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

Table 4. *Effect of the fat and protein content of milk substitute diets on the nitrogen metabolism of calves*

(Mean values with their standard errors)

	At 4 weeks of age					At 10 weeks of age				
	Treatment no. and details					Treatment no. and details				
	1+2 LFHP	3+4 HFHP	5+6 HFLP	Pooled SE of mean	Significance of difference between treatments	1+2 LFHP	3+4 HFHP	5+6 HFLP	Pooled SE of mean	Significance of difference between treatments
No. of calves	12	12	12			12	12	12		
Metabolic body size ($W^{0.73}$) (kg)	19·5	20·2	18·2	0·53	*	27·9	29·0	25·5	0·80	*
Live-weight gain/d (kg)	0·69	0·78	0·66	0·056	—	0·63	0·69	0·54	0·106	—
Dry-matter intake ($g/kg^{0.73}$ d)	54·2	52·7	54·5	1·54	—	49·1	48·4	42·8	1·96	—
N intake (g/d)	48·3	43·5	30·1	2·20	***	61·8	58·3	33·3	3·12	***
Faecal N (g/d)	2·7	2·9	2·4	0·40	—	3·6	3·6	3·2	0·34	—
Urinary N (g/d)	20·1	14·8	8·8	0·98	***	34·4	28·2	14·5	1·55	***
N balance (g/d)	25·5	25·8	18·8	1·28	***	23·8	26·5	15·7	2·13	**
($g/kg^{0.73}$ d)	1·29	1·27	1·03	0·051	**	0·84	0·91	0·61	0·062	**
Adjusted N balance										
(g/d)†	24·9	25·2	19·9	0·63	***	21·8	24·1	20·1	1·21	*
($g/kg^{0.73}$d)‡	1·28	1·30	1·01	0·031	***	0·78	0·87	0·71	0·040	*
N balance/100 g weight gain (g)	3·37	3·15	2·72	0·171	*	2·76	2·90	2·18	0·204	*
Biological value of milk protein (%)	64·8	74·2	81·8	1·29	***	51·5	60·4	70·8	1·83	***

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

† Adjusted for differences between treatments in mean dry-matter intake (g/d) (see Table 3).

‡ Adjusted for differences between treatments in mean dry-matter intake ($g/kg^{0.73}$ d).

N metabolism (*Table* 4). In spite of the lower N intake for the calves given diet HFLP, daily faecal output did not differ between diets. However, daily urinary N output was much lower on diet HFLP than on diet LFHP, which in turn was significantly lower than that for diet HFHP.

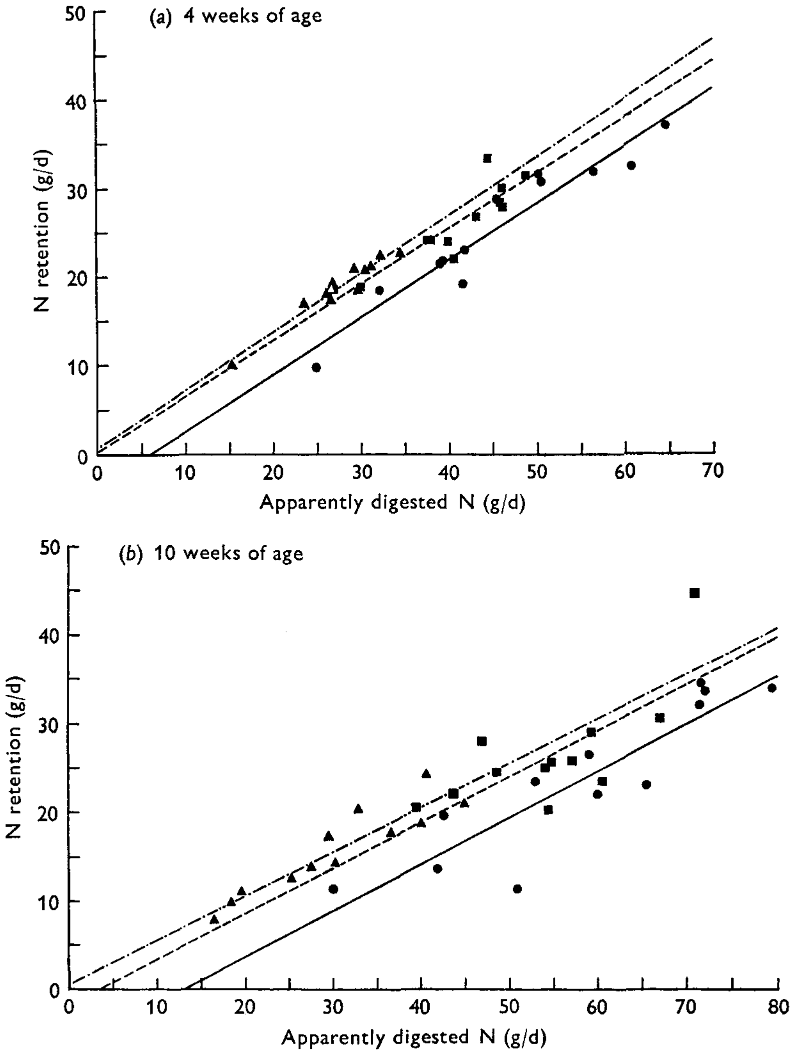

Fig. 1. Effect of different levels of protein and fat in milk substitute diets on the relationship between nitrogen retention and apparently digested N at (*a*) 4 weeks and (*b*) 10 weeks of age. ●, ——, 20% fat, high-protein diet (LFHP); ■, — —, 30%, fat, high-protein diet (HFHP); ▲, — · —, 30% fat, low-protein diet (HFLP).

N retention, as measured by N balance, was lower for the HFLP diet, but no difference occurred between the high-protein diets irrespective of whether they contained a high or low concentration of fat. Even when N retention was expressed in terms of metabolic body size, or adjusted for differences between treatment means for dry-matter intake, or when expressed in terms of metabolic body size and adjusted for differences between treatment means for dry-matter intake expressed in similar terms, no difference was found between the values for the two high-protein diets containing different fat concentrations.

N retention/100 g weight gain was lowest for the calves given the low-protein diet (HFLP); it declined with increasing age for all the diets, and at 4 weeks of age it was lower for calves given the restricted level of feeding than for those fed *ad lib.*

The biological value (BV) of protein was calculated for each of the seventy-two N balance trials by means of the values found by Roy *et al.* (1964) of 184·4 mg N/kg$^{0.73}$ live weight for endogenous urinary N excretion and 0·191 g N/100 g dry matter ingested for metabolic faecal N excretion. The mean BV differed significantly between diets, being highest for diet HFLP and lowest for diet LFHP. For the former diet, the BV at 4 weeks of age was 81·8%, which suggests that the protein content of this diet was limiting performance at this age. By 10 weeks of age, the BV of diet HFLP had fallen to 70·8%, suggesting that protein was no longer the limiting factor for growth.

No difference occurred between treatments in the slopes of the relationship between N balance (NB, g/d) and apparently digested N (ADN, g/d) at 4 or at 10 weeks of age, but there was a significant difference in position of the slopes; the individual regression lines are shown in Fig. 1 (*a*), (*b*) for 4 and 10 weeks respectively and the equations, together with the residual standard deviations, are given below:

Treatments	4 weeks	10 weeks
1, 2	NB = 0·641ADN − 3·73 (SD = 2·413)	NB = 0·522ADN − 6·62 (SD = 4·013)
3, 4	NB = 0·628ADN + 0·26 (SD = 2·252)	NB = 0·516ADN − 1·70 (SD = 4·578)
5, 6	NB = 0·651ADN + 0·81 (SD = 0·795)	NB = 0·499ADN + 0·66 (SD = 1·993)

The overall relationship between log urinary N (log UN, g/d) and N intake (NI, g/d) for the calves at 4 weeks of age was:

$$\log \text{UN} = 0{\cdot}0138\text{NI} + 0{\cdot}571 \ (\text{SD} = 0{\cdot}08471).$$

The intercept of this equation, equivalent to 3·725 g UN, may be used as an estimate of endogenous urinary N and gives a value of 193 ± 24·7 mg/kg$^{0.73}$ live weight, which may be compared with the value of 184 mg N/kg$^{0.73}$ obtained with Ayrshire calves at the same age given whole milk (Roy *et al.* 1964). The results at 4 weeks of age were used, as they included values obtained when the amount of N in the diet was probably the limiting factor for growth. Since there was a difference between treatments in position and slope of the regressions, the individual relationship of log UN and NI for the calves given the low-protein diet (HFLP) was also obtained. The relationship was:

$$\log \text{UN} = 0{\cdot}0197\text{NI} + 0{\cdot}342 \quad (\text{SD} = 0{\cdot}03348).$$

The intercept of this equation, equivalent to 2·20 g UN, gives a value for endogenous urinary N of 121 ± 18·7 mg/kg$^{0.73}$, which is considerably lower than the overall value.

The relationships between N intake/100 g dry-matter intake (NI_{100}, g/d) and ADN/100 g dry-matter intake (ADN_{100}, g/d) for calves at 4 and 10 weeks of age, together with the residual standard deviations, were:

$$4 \text{ weeks} \ \ \text{ADN}_{100} = 0{\cdot}983\text{NI}_{100} - 0{\cdot}192 \quad (\text{SD} = 0{\cdot}1109),$$
$$10 \text{ weeks} \ \ \text{ADN}_{100} = 1{\cdot}014\text{NI}_{100} - 0{\cdot}330 \quad (\text{SD} = 0{\cdot}1123).$$

Table 5. *Values for calcium and phosphorus retention, calculated from nitrogen balance using the factors of Mitchell & McClure* (1937), *and a comparison of calculated and observed Ca retention in calves*

	Treatment no. and details											
	At 4 weeks of age						At 10 weeks of age					
	1	2	3	4	5	6	1	2	3	4	5	6
	LFHP		HFHP		HFLP		LFHP		HFHP		HFLP	
N balance (g/d)	29·7	21·3	26·2	25·3	19·4	18·3	24·8	22·8	25·9	27·2	15·5	15·9
Calculated												
P retention (g/day) (N balance × 0·27)*	8·0	5·8	7·1	6·8	5·2	4·9	6·7	6·1	7·0	7·3	4·2	4·3
Ca retention (g/d) (P retention × 1·71)*	13·7	9·8	12·1	11·7	9·0	8·4	11·4	10·5	12·0	12·6	7·2	7·4
Observed												
Ca retention (g/d)	11·9	8·9	9·9	9·5	7·7	7·9	11·9	11·0	12·0	12·2	7·7	8·3

* Factors obtained from Mitchell & McClure (1937).

Table 6. *Effect of the fat and protein content of milk substitute diets on the haematological picture of calves*

(Mean values and residual standard deviations between calves)

	Treatment no. and details: 1+2 LFHP	3+4 HFHP	5+6 HFLP	Restricted	*ad lib.*	SD	Regression coefficient of change with age on value at birth	Significance of difference between: Level of feeding	Diets
No. of calves	16	18	20	26	28				
Packed cell volume									
Value at birth (%)	40	42	39	41	40	5·8		—	—
Change with age (%/d)	−0·18	−0·16	−0·14	−0·17	−0·15	0·07	−0·0086***	—	—
Adjusted change with age (%/d)†	−0·18	−0·15	−0·15	−0·16	−0·16	0·04		—	*
Haemoglobin									
Value at birth (g/100 ml)	12·6	12·5	11·8	12·9	11·7	1·8		*	—
Change with age (g/100 ml d)	−0·057	−0·045	−0·041	−0·052	−0·043	0·022	−0·0086***	—	—
Adjusted change with age (g/100 ml d)†	−0·054	−0·043	−0·045	−0·047	−0·048	0·016		—	*
Erythrocyte count									
Value at birth (10^{-6}/mm³)	7·4	7·3	6·9	7·2	7·2	1·0		—	—
Change with age (10^{-6}/mm³ d)	−0·013	−0·004	−0·007	−0·007	−0·009	0·014	−0·0086***	—	—
Adjusted change with age (10^{-6}/mm³ d)†	−0·011	−0·004	−0·009	−0·007	−0·009	0·011		—	—
Mean corpuscular volume									
Value at birth (μm³)	54·1	56·5	55·3	56·1	54·6	7·5		—	—
Change with age (μm³/d)	−0·17	−0·19	−0·15	−0·18	−0·16	0·09	−0·0085***	—	—
Adjusted change with age (μm³/d)†	−0·18	−0·18	−0·15	−0·17	−0·16	0·07		—	—
Mean corpuscular haemoglobin concentration									
Value at birth (%)	31·0	31·0	31·8	32·4	30·3	5·9		—	—
Change with age (%/d)	+0·004	+0·004	−0·017	−0·006	−0·002	0·075	−0·0103***	—	—
Adjusted change with age (%/d)†	+0·001	+0·001	−0·012	+0·005	−0·012	0·043		—	—
Erythrocyte sedimentation rate									
Value at birth (mm/24 h)	1·4	1·2	1·6	1·3	1·5	1·3		—	—
Daily change with age (mm/24 h)	+0·023	+0·040	+0·025	+0·036	+0·024	0·035	−0·0088*	—	—
Adjusted daily change with age (mm/24 h)†	+0·023	+0·039	+0·027	+0·035	+0·025	0·034		—	—
Total leucocyte count									
Value at birth (10^{-3}/mm³)	8·7	10·1	8·2	9·3	8·7	2·3		—	*
Change with age (10^{-3}/mm³ d)	−0·007	−0·024	−0·013	−0·014	−0·015	0·030	−0·0096***	—	—
Adjusted change with age (10^{-3}/mm³ d)†	−0·010	−0·014	−0·020	−0·011	−0·018	0·021		—	—

Table 6 *cont.*

	Treatment no. and details						Regression coefficient of change with age on value at birth	Significance of difference between	
	1+2 LFHP	3+4 HFHP	5+6 HFLP	Restricted	*ad lib.*	SD		Level of feeding	Diets
No. of calves	16	18	20	26	28				
Band neutrophils as % of total leucocyte count†									
Value at birth§	0·81	0·84	0·77	0·79	0·83	0·34		—	—
Change with age/d§	−0·0001	−0·0007	+0·0004	0	−0·0003	0·003	−0·0080***	—	—
Adjusted change with age/d§	−0·0001	−0·0004	+0·0001	−0·0002	−0·0002	0·002		—	—
Adult neutrophils as % of total leucocyte count‡									
Value at birth	53·4	54·8	62·9	56·9	57·6	12·5		—	*
Change with age/d	−0·18	−0·21	−0·24	−0·21	−0·20	0·17	−0·0115***	—	—
Adjusted change with age/d†	−0·22	−0·23	−0·17	−0·22	−0·20	0·10		—	—
Lymphocytes as % of total leucocyte count‡									
Value at birth	45·7	44·3	36·1	42·4	41·3	12·0		—	*
Change with age/d	+0·16	+0·20	+0·23	+0·20	+0·20	0·17	−0·0115***	—	—
Adjusted change with age/d†	+0·21	+0·23	+0·17	+0·21	+0·19	0·09		—	LFHP + HFHP > HFLP*
Monocytes as % of total leucocyte count‡									
Value at birth§	0·96	0·87	0·92	0·91	0·92	0·42		—	—
Change with age/d§	+0·0014	+0·0083	+0·0013	+0·0024	+0·0050	0·015	−0·0116*	—	—
Adjusted change with age/d†§	+0·0019	+0·0078	+0·0014	+0·0023	+0·0050	0·014		—	—
Eosinophils as % of total leucocyte count‡									
Value at birth§	0·73	0·77	0·83	0·72	0·84	0·21		*	—
Change with age/d§	+0·0048	−0·0002	+0·0015	+0·0025	+0·0015	0·0054	−0·0118***	—	*
Adjusted change with age/d†§	+0·0042	−0·0003	+0·0021	+0·0018	+0·0021	0·0049		—	**
Platelet count									
Value at birth (10^{-3}/mm³)	268	258	265	261	267	31		—	—
Change with age (10^{-3}/mm³ d)	−0·11	0	−0·10	−0·08	−0·06	0·56	−0·0124***	—	—
Adjusted change with age (10^{-3}/mm³ d)†	−0·06	−0·07	−0·08	−0·12	−0·02	0·40		—	—

* Significant at $P < 0·05$. ** Significant at $P < 0·01$. *** Significant at $P < 0·001$.
† Adjusted for differences between treatment means in values at birth.
‡ No. of calves: treatments 1+2, 19; treatments 3+4, 21; treatments 5+6, 22.
§ Values transformed thus $\sqrt{(x+0·5)}$.

The intercept of the equation obtained at 4 weeks of age may be used to give an estimate of metabolic faecal N excretion. The value obtained, namely 0.19 ± 0.112 g N/100 g dry-matter intake, is the same as the total faecal N excreted by Ayrshire calves at the same age given whole milk (Roy *et al.* 1964). The N of whole milk does not therefore leave any significant indigestible residue. The value obtained at 10 weeks of age suggests that metabolic faecal N excretion per unit of dry matter increases with age. However, as the true digestibility of N cannot be greater than 100%, the value of 0.33 ± 0.116 g/100 g dry matter ingested must be an overestimate and must therefore be treated with caution.

The true digestibility of protein at both 4 and 10 weeks of age was calculated, using the metabolic faecal N value of 0.192 g N/100 g dry-matter intake, and the results are given in Table 3. Although there was no significant difference between treatments, the calves given the low-protein diet (HFLP) tended to have a lower value at 10 weeks of age.

Phosphorus and Ca retention values were calculated from N retention using the factors obtained by Mitchell & McClure (1937), in which P retention = N retention × 0.27 and Ca retention = P retention × 1.71. The Ca retention values so obtained were compared with the observed values and are presented in Table 5, which shows that good agreement was obtained between the observed and calculated Ca retention values at 10 weeks of age, but at 4 weeks the calculated values overestimated Ca retention.

Table 7. *Effect of the fat and protein content of milk substitute diets on measurements made on the calves at slaughter*

(Mean values with their standard errors)

	Treatment no. and details			Pooled SE of mean	Significance of difference between treatments
	1+2 LFHP	3+4 HFHP	5+6 HFLP		
No. of calves	24	24	24		
Fasted weight at slaughter (kg) A	110.0	111.0	106.2	1.6	—
Dressed carcass weight (kg) B	64.2	65.4	63.1	1.2	—
Killing out %, 100 B/A	58.1	58.7	59.2	0.51	—
Weight of perirenal fat (kg)	1.58	2.25	1.89	0.12	**
Adjusted weight of perirenal fat (kg)†	1.54	2.17	2.00	0.11	***

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

† Adjusted for differences between treatments in mean fasted weight at slaughter ($b = 0.040 \pm 0.0085$***).

Haematological measurements

The haematological findings, expressed as values at birth, before suckling and as mean daily changes with age, together with mean daily changes adjusted for differences in mean value at birth are given in Table 6. For all measurements the regression coefficients of change with age on value at birth were negative. Thus, when there was an increase in value with increasing age, high values at birth increased less than low values at birth. When, on the other hand, there was a decrease with age, high values at birth fell more than low values.

The decline in packed cell volume and haemoglobin content with age, after adjustment for differences between treatments in mean value at birth, was significantly reduced in calves given the high-fat diets (HFHP and HFLP). The high-protein diets, irrespective of their content of fat, significantly enhanced the rate of increase with age in the percentage of lymphocytes. A marked difference occurred in the change with age in the percentage of eosinophils; the percentage increased with age for calves given diets LFHP and HFLP, but decreased with age for those given the diet high in energy and protein (HFHP).

Measurements made after slaughter

The values are given in Table 7. Fasted weight at slaughter, carcass weight and killing out percentage did not differ between treatments. Perirenal fat deposition was greatest for calves given the high-fat, high-protein diet (HFHP) and lowest for those given the low-fat diet (LFHP). Age of the calf at slaughter had no effect on the weight of perirenal fat. After adjustment for differences in mean fasted weight at slaughter, perirenal fat deposition did not differ between calves given the high-fat diets (HFHP and HFLP); both these diets resulted in much greater fat deposition than the low-fat diet (LFHP).

DISCUSSION

The results of this experiment show clearly that increasing the energy content of a milk substitute by increasing the fat content from 20 to 30% of the dry matter will not result in increased N retention, even when energy is the limiting factor for growth. Such addition of fat results only in increased fat deposition in the carcass. Czako (1964) has also shown that varying the amount of fat in a milk diet produced no marked differences in N metabolism. It seems very unlikely that the inclusion of butylated hydroxyanisole in the diets would have affected fat metabolism, although it cannot be entirely discounted since there is some evidence that, at extremely high levels of intake, deposition of the antioxidant in depot fat may occur (FAO, 1962).

This finding does not appear to be related to the fact that maximum N retention has been reached, since on the low-protein diet (HFLP), N retention was considerably lower than for the other two diets, but perirenal fat deposition was almost the same as that obtained with calves given the other high-fat diet (HFHP). A possible explanation is that the calves given the low-protein diet (HFLP) received a diet that was limiting in protein during the first 5 weeks of life, as judged by the biological value of protein of 81·8% during the balance period at 4 weeks of age, and that at this time, surplus energy was being stored as fat, which was subsequently observed as increased perirenal fat deposition at slaughter. The significantly lower N balance observed at 10 weeks of age on the HFLP diet, compared with that on the two diets high in protein, was largely a reflection of the significantly lower intake of dry matter. The decline in BV from 81·8% at 4 weeks to 70·8% at 10 weeks with diet HFLP suggests that energy and not protein was the limiting factor for growth at the older age.

Since the major ingredients of diets LFHP and HFHP were fat and skim-milk powder, increasing the fat content of the diet from 20 to 30% resulted in a reduction in the protein content from 29 to 26%, and an increase in the energy content from 5·2 to 5·6 kcal/g dry matter. Thus, the percentage of the digestible energy derived from protein was reduced from 33 to 27%. The slightly higher N intake of calves given diet LFHP was accompanied by a higher output of N in the urine, and the amount of N retained was slightly, although not significantly, depressed. Thus, there was a significantly lower BV of protein for diet LFHP and it follows, therefore, that the efficiency of utilization of the protein of the diet was greater when the high-fat diet (HFHP) was fed. It seems probable that this effect was due to the lower protein content of diet HFHP, rather than to its higher energy content, and it is interesting to speculate, therefore, whether a more readily available source of energy would have resulted in an increase in the amount of N retained.

The calves given the low-protein diet (HFLP) had considerably lower growth rates than those given the high-protein diets (LFHP and HFHP) and it thus appears that 19% protein (20% of digestible energy derived from protein) in a milk substitute diet for calves is insufficient to allow maximum growth, at least during the first 4 weeks of life. This protein content is considerably higher than that found to be limiting for calves given solid food (Stobo, Roy & Gaston, 1967*a*–*c*), since a protein content in the concentrates of 18·7% on a dry-matter basis was optimal for maximum growth rates, whereas 14·3% proved to be limiting. This requirement of the milk-fed calf for a higher protein content in the diet than that required by calves given dry diets is probably related to the combined effect of the lower dry-matter intake from liquid diets and the higher efficiency of utilization of the energy of such diets.

It seems probable that the weight of perirenal fat gives a fair estimate of total fat deposition. From the results of Fraser (1961) and of Barton & Kirton (1961) it can be calculated that at 50 kg carcass weight, perirenal and channel fat together comprised 24·6 and 23·2% of the total weight of carcass fat for calves given liquid diets of widely different fat content, namely whole milk (*c*. 29% fat) and buttermilk (12% fat) respectively. Similarly, Butterfield (1963) considered that the weight of kidney and channel fat might be a useful indicator of total carcass fat and obtained a correlation coefficient of 0·91, using twenty-nine steers. From the mean value of Barton & Kirton (1961), an estimate of the total carcass fat in the calves given the three diets in the present experiment may be made, namely 6·6, 9·4 and 7·9 kg fat for diets LFHP, HFHP and HFLP respectively. These values are equivalent to 10·3, 14·4 and 12·5% fat in the carcasses for the three treatments respectively and may be compared with the values of 8·2 and 11·9% fat for veal calves of 106 and 152 kg live weight found by Amich Gali & Rossi, (1967).

The low apparent digestibility of protein in low-protein diets has been observed by many other workers; but, as shown in the present experiment, this is the result of faecal N being largely of metabolic origin so that the true digestibility of protein is unaffected by protein concentration in the diet.

The finding that the high-fat diets (HFHP and HFLP) reduced the rate of decline with age in packed cell volume and haemoglobin content is difficult to explain. Such a finding for diet HFLP might have been expected owing to the lower growth rate of the calves on this treatment. Possibly the effect was due to a slower rate of increase in plasma volume with age for the calves given the high-fat diets.

The slower rate of increase with age in the lymphocytes as a percentage of total leucocyte count in calves given the low-protein diet (HFLP) may have been the result of a deficiency in protein. Aschkenasy (1964) has shown that deprivation of protein for 28 d in rats resulted in a reduction in total lymphocyte count. The very marked reduction in the percentage of eosinophils with age for the calves given the HFHP diet, which had the highest energy content, may well have been the result of stress, as eosinophil numbers are known to be inversely related to the amount of circulating adrenocortical hormones (Schultze, 1957). The calves on this diet also showed a higher mean rectal temperature throughout the experimental period.

The changes with age in the various haematological values that were unaffected by treatment are similar to those obtained by Roy *et al.* (1964) for calves given whole milk together with Fe injections at the same level as in the present experiment.

From a practical viewpoint, the results of this experiment show that there is no advantage to be gained by increasing the fat content of a milk substitute above 20%, unless increased fat deposition is required. Moreover, to obtain maximum growth rate, milk substitutes should certainly contain more than 19% protein, when given during the first 5 weeks of life. The minimum protein content of a milk substitute diet for maximum growth during this early period of life is probably not much below 26%.

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