The nutrition of the veal calf

The effect of anaemia and of iron and chlortetracycline supplementation on the performance of calves given large quantities of whole milk

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With the introduction of intensive liquid-feeding systems of fattening calves for veal and the demand for a pale flesh, the effect of anaemia on the performance of calves is clearly of importance.

It is well known that anaemia develops in calves restricted to a milk diet for long periods, and that the condition can be alleviated by administration of iron (Cannon, 1931). The rate of growth of the calf, however, probably affects the age at which a condition of severe anaemia develops (Blaxter, Sharman & MacDonald, 1957). In the work of Herman (1936) with Holstein calves having initial haemoglobin values of about 11·5 g/100 ml and gaining about 0·68 kg/day, haemoglobin levels did not fall to 5 g/100 ml blood until the calves were at least 289 days of age. Similarly, Knoop, Krauss & Washburn (1935) found that a supplement of 400 mg Fe and 40 mg copper daily had no effect on the weight gain of calves during the first 112 days of life; at this age haemoglobin levels of the unsupplemented group varied from 3·4 to 7·8 g/100 ml. More recently, Blaxter *et al.* (1957) produced anaemia in four calves kept under laboratory conditions in which stringent precautions were taken to prevent access to Fe. During the first 6 weeks of life the weight gains of the two control calves given Fe and the four calves given no Fe were similar at 0·35 kg/day whereas, during the subsequent 6-week period, the calves given Fe gained 0·67 kg/day and the calves given no Fe gained 0·49 kg/day. After 12 weeks of age the beneficial effect of Fe supplementation was even more marked. In a field experiment with forty-six pairs of suckling beef calves (Blaxter *et al.* 1957), a daily supplement of 35 mg Fe increased haemoglobin content and mean corpuscular volume, but no measurement of the effect on performance was made. Niedermeier, Allen, Lance, Rupnow & Bray (1959) found no significant effect of a supplement of 240 mg Fe and 7 mg Cu daily on the weight gain of calves given whole milk *ad lib.* to 39 days of age; at this age calves given the supplement had a haemoglobin value of 15·3 and those given no supplement a value of 8 g/100 ml.

Even with calves reared by conventional methods and having access to dry food,

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haemoglobin content falls during the first 3–8 weeks of life and then recovers (Wise, Caldwell, Parrish, Flipse & Hughes, 1947; Thomas, Okamoto, Jacobson & Moore, 1954; Owen, Voelker, Jacobson & Allen, 1955; Wing, Jacobson & Allen, 1955). Similar results have been found with calves given a milk substitute, consisting of skim milk, dextrose and soya-bean oil meal, in place of whole milk, although the inclusion of corn distillers dried solubles resulted in higher haemoglobin levels (Ratcliff, Jacobson & Allen, 1958). This transitory depression in haemoglobin content may have an effect on performance, since calves with a minimum haemoglobin content of less than 8 g/100 ml had weight gains that were 96% of the normal rate compared with 106% of normal rate for those with haemoglobin levels greater than 8 g/100 ml (Thomas *et al.* 1954).

That calves may be deficient in Fe at birth has been shown by Hibbs, Conrad & Gale (1961) who found that 30% of the calves born at the Ohio experimental station during 12 years had haemoglobin values of less than 9 g/100 ml, with a range at birth of 5–15 g/100 ml. Injection of 500 mg Fe dextran was effective in raising haemoglobin levels but did not enhance the weight gains of those with low haemoglobin levels at birth. Injections of 1–2 g Fe dextran into cows, 1–38 days prepartum, had no effect on the haematological condition of their calves. In further work, no differences were found in basal metabolic, pulse and respiration rates or in heart, liver and spleen weights between normal and anaemic calves during the period 3–22 days of age (Settlemire, Hibbs & Conrad, 1962).

The sex and breed of the calf also influences the haemoglobin content, females having a higher content than males (Thomas *et al.* 1954) and Red Danish and Sindhi–Jersey crossbreds having higher values than Jerseys or Holsteins (Jacobson & Moore, 1948; Rusoff, Frye & Scott, 1951; Thomas *et al.* 1954). The use of heated buildings for veal production may possibly affect the haemoglobin level, since Kazakova (1959) in Lithuania has shown that calves born in January and reared in unheated buildings with a mean temperature in February and March of from $-4{\cdot}8°$ to $-1{\cdot}6°$ had higher haemoglobin levels than those reared in heated buildings maintained at a temperature of from $+6°$ to $+9°$.

In a preliminary trial with eight Ayrshire and four Shorthorn calves given large volumes of whole milk (Roy & Shillam, 1961, 1962) weight gains and digestibility of the proximate constituents of the milk declined progressively from 8 weeks of age with a concomitant increase in the incidence of scouring. Up to this age, the calves were gaining weight at 0·80–0·95 kg/day. One calf died at 101 days of age and at post-mortem showed the general lesions of an *Escherichia coli* localized intestinal infection, a condition that normally afflicts calves during the first 3 weeks of life. However, in this calf the gall bladder was also congenitally absent. Two further calves in poor condition had to be slaughtered because it was not possible to rear them to the slaughter weight of 115 kg. By 8 weeks of age, the mean haemoglobin content of the calves was 6 g/100 ml and by 12 weeks 5 g/100 ml.

An experiment was therefore planned to find whether the reduction in performance could be prevented by chlortetracycline supplementation, or by Fe injections, or by a combination of both treatments.

METHODS

Plan of experiment

The experiment of randomized block design was done from October 1961 to August 1962 and consisted of four treatments in each of seven blocks of Ayrshire bull calves as follows:

Treatment no.	Colostrum	Basal diet and supplement
1	7 kg whole colostrum	Whole milk
2		Whole milk + chlortetracycline
3		Whole milk + Fe injections
4		Whole milk + chlortetracycline + Fe injections

Diets and supplements

Colostrum. Each calf was given, within 48 h of birth, 7 kg whole colostrum, obtained from the first two milkings after parturition from seventeen Ayrshire, thirteen Friesian and five Shorthorn cows. The calves within each block received a blend of the same batches of colostrum, but the batches differed between blocks.

Milk. Whole milk from the Institute herd was used. On average the weekly samples of the milk contained 3·8% fat and 8·8% solids-not-fat. The quantity of milk was adjusted weekly, the calves being given sufficient, on the basis of 53 kcal gross energy daily/kg body-weight for maintenance and 2360 kcal gross energy daily/kg weight gain (Roy, Shillam, Hawkins & Lang, 1958), for 0·5 kg gain/day for the first 7 days of whole-milk feeding, for 1·0 kg gain/day for the next 5 days, and thereafter for 1·25 kg gain/day. When scouring occurred, the allowance of milk was reduced to that required for maintenance until the consistency of the faeces returned to normal.

Chlortetracycline. Chlortetracycline hydrochloride, 12 mg/kg milk, was added to the diet of calves in treatments 2 and 4. Aureomycin Soluble (Tinted) Powder (Cyanamid of Great Britain Ltd) containing 25 g chlortetracycline hydrochloride/lb was used. A solution of the powder, 1 g/6 ml distilled water, was prepared daily, and 1·4 ml solution/kg milk were added just before feeding.

Fe. The calves in treatments 3 and 4 were given a total supplement of 1500 mg Fe, in the form of 5 ml Fe dextran containing 100 mg Fe/ml (Imposil 200; Bengers Laboratories Ltd), injected intramuscularly into the trapezius muscle of the neck on the 7th, 14th and 21st days of age; alternate sides were used for consecutive injections.

Calves

The calves were collected within a few hours of birth from farms within a 12-mile radius of Shinfield. The turbidity test of Aschaffenburg (1949) was made on the serum of the calves to ensure that they had not suckled their dams.

Four blocks of calves were reared in wooden crates and three blocks on wooden slatted floors or on expanded-metal floors coated with nylon or plastic (The Expanded Metal Co. Ltd) in pens that had cement-rendered walls, wooden gates and ungalvanized

iron bucket rings. There were two exceptions in the first block, in which the calves in treatments 1 and 4 were reared on uncoated expanded-metal floors. The calves were pail-fed twice daily at 08.00 and 17.00 h from tinned-metal buckets.

The calves were weighed weekly, the incidence of scouring was recorded daily, and the rectal temperature taken daily for the first 14 days of life and weekly thereafter.

Blood samples were taken from the jugular vein of all the calves before their first feed and 2–3 h after the morning feed at weekly intervals to 4 weeks of age and thereafter at fortnightly intervals. The blood was collected into a 5 ml tube containing an anticoagulant mixture (Heller & Paul, 1934). Blood films for differential counts and study of cell morphology were made as soon as practical.

Digestibility and nitrogen balance trials were made with four blocks of calves at 4 weeks and at 10 weeks of age and on two of the four blocks at 7 weeks of age. The calves were placed in individual galvanized-metal metabolism crates for 7-day collection periods beginning at 17.00 h before the evening feed.

The calves were reared to 115 kg live weight and were slaughtered on the Tuesday after this weight was reached. No milk was given on the morning of slaughter and only half their normal allowance at the evening feed on the day before slaughter.

Immediately after slaughter, the skin, pluck and digestive tract were removed and weighed. The digestive tract was then ligatured between the reticulo-rumen and omasum, between the omasum and abomasum, and between the abomasum and duodenum. The component parts after separation were weighed, cut open and the contents removed; after being washed the parts were allowed to drain for 6 h before they were re-weighed. Empty body weight was then calculated.

A composite sample of each lobe of the liver was taken for carotenoid and vitamin A determinations and the remainder, together with a sample of the pectoral muscle, was kept at $-20°$ until Fe estimations could be made.

Analytical methods

Milk. The proximate composition of the milk used for all the blocks, and the carotenoid and vitamin A contents of colostrum and of twenty-one samples of milk given to the calves in blocks 4–7, were determined by the methods used by Rowland, Roy, Sears & Thompson (1953).

Faeces and urine. N was determined in urine and acidified faeces by the Kjeldahl method. The remainder of the faeces was dried to constant weight at 100° and the dry-matter content calculated. Fat was determined in the dry faeces by a modification of the Werner Schmid method (Davis & Macdonald, 1953), ash by incineration in an electric muffle furnace at a temperature not exceeding 550°, and calcium by precipitation as oxalate from a solution of the ash, and titration with permanganate.

Liver and muscle. Vitamin A and carotene were extracted from the liver by the method of Thompson, Ganguly & Kon (1949) and determined by the antimony trichloride reaction in the photoelectric spectrophotometer of Thompson (1949).

Liver Fe was determined in a 40–50 g sample, and muscle Fe in a 30 g sample, by wet oxidation and, after dilution of the digest to 100 ml with water, by a modification of the thiocyanate method of Ventura & Klopper (1951).

Haematological measurements. The erythrocyte sedimentation rate (ESR), haemoglobin content, platelet count, and total and differential leucocyte counts were determined by the techniques adopted by Greatorex (1954). Packed cell volume (PCV) was obtained by centrifugation in micro-haematocrit tubes at 16355 *g* for 5 min. Mean corpuscular volume (MCV) was calculated from the packed cell volume and erythrocyte counts and mean corpuscular haemoglobin concentration (MCHC) from the packed cell volume and haemoglobin content. Blood urea was determined with an MRC Grey-wedge photometer by procedures adapted from King & Wootton (1956).

Statistical analysis

In the analysis of the results for the incidence of scouring and for certain haematological measurements, namely the percentage of band neutrophils, monocytes and eosinophils, the values (x) were transformed to $\sqrt{(x+\frac{1}{2})}$.

RESULTS

Performance to 12 weeks and to slaughter

The results for the performance of the calves to 12 weeks of age and to slaughter are given in Table 1 and Fig. 1.

Mortality. One calf in treatment 1 died at 6 days of age and was replaced; death was associated with an *E. coli* localized intestinal infection.

Incidence of scouring. Chlortetracycline supplementation significantly reduced the incidence of scouring during the first 12 weeks of life. From 12 weeks to slaughter, the calves given the Fe supplement tended to have a lower incidence of scouring.

Milk refusals. Milk refusals to 12 weeks of age tended to be less for the calves given the Fe supplement, but the difference was not significant. From 12 weeks to slaughter, there was a large variation in milk refusals between individual calves, but there was a tendency for the refusals to be greatest for calves given either chlortetracycline or Fe.

Weight gain. Fe supplementation significantly increased the weight gain to 12 weeks of age. The effect was of higher significance when weight gain from birth to slaughter was considered. The type of pen in which the calves were reared had no effect on weight gain, even within the treatments in which no Fe was given. When daily liveweight gain to 12 weeks was adjusted for differences between treatments in mean birth weight and total milk consumption by means of the appropriate partial regression coefficients, there were no significant differences between treatments.

No calf was kept on experiment after 136 days of age, and by this time two calves in treatment 1 and one in treatment 3 had not achieved 115 kg live weight. In addition two calves in treatment 2 were slaughtered at 106 and 127 days respectively because their weights had remained constant for 1 month at 85–98 kg.

Age to 100 kg live weight was significantly less for the calves given the Fe supplement, both before and after adjustment for differences between treatments in mean birth weight.

Table 1. *Effect of chlortetracycline and iron supplementation on the performance of calves given large volumes of whole milk*

(Mean values with their standard errors or ranges)

	Treatment no. and details					Significance of main effects	
	1 Control	2 Chlortetracycline	3 Fe	4 Chlortetracycline + Fe	Pooled SE of mean	Chlortetracycline	Fe
No. of calves	7	7	7	7	—	—	—
Birth weight (kg)	32·8	36·4	35·1	35·1	±1·88	—	—
Milk consumption (0–84 days) (kg)	672·1	730·0	735·0	761·3	±22·30	—	—
Milk refusals (0–84 days) (kg)	23·2	17·5	9·7	5·4	±8·07	—	—
No. of days on which calves scoured (0–84 days)	3 (range 0–6)	2 (range 0–9)	2 (range 0–6)	0 (range 0–2)	—	*	—
Live-weight gain/day (0–84 days) (kg)	0·76	0·84	0·86	0·93	±0·036	—	*
Adjusted live-weight gain/day (0–84 days) (kg)†	0·84±0·020	0·85±0·017	0·84±0·017	0·86±0·018	—	—	—
No. of days on which calves scoured (84 days to slaughter)	2 (range 0–15)	4 (range 0–15)	0 (range 0–2)	0 (range 0–2)	—	—	—
Milk refusals (84 days to slaughter) (% of milk offered)	2·3	7·6	4·0	2·2	—	—	—
Age to 100 kg live weight (days)	96	89	83	76	±5·5	—	*
Adjusted age to 100 kg live weight (days)‡	92±4·8	92±4·7	83±4·6	76±4·6	—	—	*
Live-weight gain/day (0 days to slaughter) (kg)	0·73	0·75	0·84	0·91	±0·047	—	**
Conversion rate (kg milk solids/kg live-weight gain)	1·60	1·56	1·41	1·33	±0·070	—	**
Adjusted conversion rate (kg milk solids/kg live-weight gain)§	1·49±0·023	1·47±0·023	1·45±0·022	1·47±0·024	—	—	—

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

† Adjusted for differences between treatment groups in mean birth weight and total milk consumption to 84 days.

‡ Adjusted for differences between treatment groups in mean birth weight.

§ Adjusted for differences between treatment groups in mean live-weight gain/day.

Food conversion rate. Conversion rate was highly significantly reduced by Fe supplementation; this effect appeared to be due mainly to differences in live-weight gain, as calves gaining weight slowly use a greater proportion of their energy intake for maintenance purposes than those gaining weight more rapidly; moreover there were only small differences in the requirement of digestible energy for weight gain above maintenance (see p. 495). After adjustment for differences between treatments in mean live-weight gain, conversion rate was similar in all treatments.

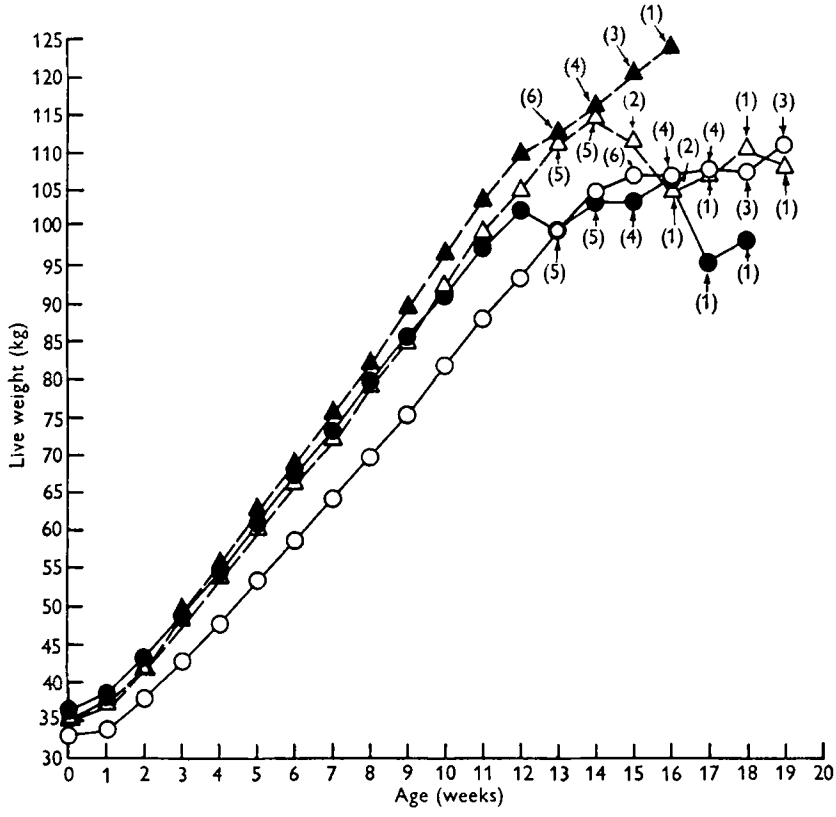

Fig. 1. Effect of chlortetracycline and iron supplementation on the growth rate of calves given large volumes of whole milk. ○—○, control; ●—●, chlortetracycline; △ – – △, Fe; ▲ – – ▲, chlortetracycline + Fe. Figures in parentheses are the numbers of calves included in the value.

Performance during 14-day periods

In Table 2, the results are given for 14-day periods. In each period adjustment of live-weight gain has been made for differences in treatment mean initial weight and milk consumption. It may be argued that this is unjustified for periods other than the first, since initial weight in the succeeding periods would be influenced by treatment effects. However, as the calves were given a quantity of milk that would give the same weight gain within each period irrespective of initial weight, the adjustments would appear to be justified.

Table 2. *Effect of chlortetracycline and iron supplementation on performance during fortnightly periods of calves given large volumes of whole milk*

(Mean values with their standard errors or ranges)

	Treatment no. and details					Significance of main effects and interaction		
	1 Control	2† Chlortetracycline	3 Fe	4 Chlortetracycline + Fe	Pooled SE of mean	Chlortetracycline	Fe	Interaction
0–14 days:								
Birth weight (kg)	32·8	37·2 ± 2·09	35·1	35·1	± 1·89	—	—	—
Milk consumption (kg)	61·7	71·8 ± 3·25	68·0	71·8	± 2·94	*	—	—
Milk refusals (kg)	4·1	1·5	1·2	0·9	± 1·69	—	—	—
No. of days on which calves scoured	1 (range 0–4)	0 (range 0–2)	0 (range 0–1)	0 (range 0–1)	—	*	—	—
Live-weight gain/day (kg)	0·37	0·54 ± 0·043	0·56	0·56	± 0·039	*	*	—
Adjusted live-weight gain/day (kg)‡	0·45 ± 0·023	0·51 ± 0·023	0·57 ± 0·020	0·50 ± 0·021	—	—	*	*
14–28 days:								
Live weight at 14 days (kg)	37·6	44·2 ± 2·25	42·3	42·5	± 2·04	—	—	—
Milk consumption (kg)	94·6	110·2 ± 4·83	105·7	109·9	± 4·37	*	—	—
Milk refusals (kg)	7·9	1·6	1·7	0·5	± 2·88	—	—	—
No. of days on which calves scoured	0 (range 0–1)	(0 (range 0–1)	1 (range 0–2)	0 (range 0)	—	—	—	—
Live-weight gain/day (kg)	0·70	0·87 ± 0·057	0·82	0·90	± 0·051	*	—	—
Adjusted live-weight gain/day (kg)‡	0·78 ± 0·035	0·84 ± 0·034	0·82 ± 0·028	0·84 ± 0·029	—	—	—	—
28–42 days:								
Live weight at 28 days (kg)	47·4	56·3 ± 2·60	53·8	55·1	± 2·35	*	—	—
Milk consumption (kg)	103·7	124·8 ± 4·24	119·5	123·6	± 3·84	**	—	*
Milk refusals (kg)	6·8	2·4	3·5	1·0	± 2·01	—	—	—
No. of days on which calves scoured	1 (range 0–2)	0 (range 0)	0 (range 0)	0 (range 0)	—	*	*	*
Live-weight gain/day (kg)	0·78	0·96 ± 0·044	0·88	0·97	± 0·039	**	—	—
Adjusted live-weight gain/day (kg)‡	0·90 ± 0·035	0·90 ± 0·029	0·87 ± 0·024	0·92 ± 0·026	—	—	—	—

42–56 days:								
Live weight at 42 days (kg)	58·3	70·3 ± 2·77	66·1	70·0	± 2·50	*	—	—
Milk consumption (kg)	121·3	138·8 ± 3·87	132·2	136·8	± 3·50	**	—	—
Milk refusals (kg)	3·6	2·7	0·7	0·8	± 1·99	—	—	—
No. of days on which calves scoured	0 (range 0–2)	0 (range 0–1)	0 (range 0–3)	0 (range 0–1)	—	—	—	—
Live-weight gain/day (kg)	0·80	0·91 ± 0·042	0·88	0·94	± 0·038	*	—	—
Adjusted live-weight gain/day (kg)‡	0·84 ± 0·040	0·88 ± 0·034	0·88 ± 0·027	0·93 ± 0·030	—	—	—	—
56–70 days:								
Live weight at 56 days (kg)	69·5	82·5 ± 3·04	78·4	81·8	± 2·75	**	—	—
Milk consumption (kg)	139·1	148·7 ± 4·60	147·8	151·4	± 4·16	—	—	—
Milk refusals (kg)	0·6	2·5	1·1	0·6	± 1·10	—	—	—
No. of days on which calves scoured	0 (range 0)	0 (range 0–3)	0 (range 0–1)	0 (range 0)	—	—	—	—
Live-weight gain/day (kg)	0·86	0·85 ± 0·078	0·97	1·05	± 0·070	—	*	—
Adjusted live-weight gain/day (kg)‡	0·86 ± 0·044	0·90 ± 0·039	0·95 ± 0·033	1·01 ± 0·036	—	—	*	—
70–84 days:								
Live weight at 70 days (kg)	81·6	94·4 ± 3·57	92·0	96·5	± 3·23	*	—	—
Milk consumption (kg)	151·8	155·6 ± 6·03	161·9	167·8	± 5·46	—	—	—
Milk refusals (kg)	0·1	6·6	1·5	1·5	± 1·73	—	—	—
No. of days on which calves scoured	0 (range 0)	1 (range 0–5)	0 (range 0–2)	0 (range 0)	—	—	—	—
Live-weight gain/day (kg)	0·84	0·76 ± 0·087	0·92	0·99	± 0·079	—	—	—
Adjusted live-weight gain/day (kg)‡	0·84 ± 0·039	0·89 ± 0·035	0·88 ± 0·031	0·90 ± 0·035	—	—	—	—

* Significant at $0{\cdot}01 < P < 0{\cdot}05$. ** Significant at $0{\cdot}001 < P < 0{\cdot}01$.

† Replacement value for one calf calculated by the missing plot technique of Yates (1933) owing to partial destruction of records.

‡ Adjusted for differences between treatment groups in mean initial weight and total milk consumption in each 14-day period.

Table 3. *Effect of chlortetracycline and iron supplementation, and the effect of age on the apparent digestibility (%) of large volumes of whole milk by calves*

(Mean values with their standard errors)

	Treatment no. and details					Significance of main effects and interaction				Significance of difference between weeks	
	1 Control	2 Chlortetracycline	3 Fe	4 Chlortetracycline + Fe	Pooled SE of mean	Chlortetracycline	Fe	Interaction	General mean with its SE	4 and 7	4 and 10
No. of calves:											
4 weeks	4	4	4	4	—	—	—	—	—	—	—
7 weeks	2	2	2	2	—	—	—	—	—	—	—
10 weeks	4	3†	4	4	—	—	—	—	—	—	—
Weight of calves (kg):											
4 weeks	47·7	55·8	54·5	55·6	±3·68	—	—	—	53·4±1·84	—	—
7 weeks	72·8	69·0	76·8	74·0	±3·68	—	—	—	73·1±1·84	—	—
10 weeks	81·6	91·7±6·29	90·9	96·0	±5·23	—	—	—	90·0±2·62	—	—
Total solids intake/day (g):											
4 weeks	926	1089	1081	1103	±69·4	—	—	—	1050±34·7	—	—
7 weeks	1209	1222	1370	1268	±88·9	—	—	—	1267±44·5	—	—
10 weeks	1371	1396±88·1	1488	1532	±73·3	—	—	—	1447±36·7	—	—
Faecal dry matter (%):											
4 weeks	16·4	18·3	17·3	17·9	±1·46	—	—	—	17·5±0·73		
7 weeks	14·8	18·0	17·6	13·4	±2·40	—	—	—	16·0±1·20	—	—
10 weeks	21·0	20·8±1·61	20·3	18·0	±1·34	—	—	—	20·0±0·67		
Apparent digestibility (%): Total solids:											
4 weeks	96·3	98·4	96·9	98·3	±1·31	—	—	—	97·5±0·65	—	—
7 weeks	95·3	96·1	96·6	96·2	±1·42	—	—	—	96·1±0·71	—	—
10 weeks	97·7	95·6±0·25	97·6	98·2	±0·21	**	***	***	97·2±0·11	—	—

Fat:											
4 weeks	95·8	98·8	95·9	98·9	±1·78	—	—	—	97·3±0·89	—	—
7 weeks	95·8	95·9	96·7	95·6	±2·02	—	—	—	96·0±1·01	—	—
10 weeks	98·2	94·9±0·52	97·8	98·6	±0·43	*	**	**	97·4±0·22	—	—
Protein:											
4 weeks	93·0	96·9	94·3	96·3	±2·95	—	—	—	95·1±1·47	—	—
7 weeks	93·0	93·4	94·5	92·6	±1·80	—	—	—	93·4±0·90	—	—
10 weeks	96·8	94·1±0·41	96·7	97·4	±0·34	*	**	**	96·3±0·17	—	—
Lactose:											
4 weeks	100·2	99·5	100·4	99·7	±0·69	—	—	—	99·9±0·35	—	—
7 weeks	98·7	99·4	99·7	100·1	±0·49	—	—	—	99·5±0·25	—	—
10 weeks	99·3	99·0±0·12	99·2	99·3	±0·10	—	—	—	99·2±0·05	—	—
Apparent absorption (%):											
Ash:											
4 weeks	89·9	96·2	93·3	97·4	±3·43	—	—	—	94·2±1·71		
7 weeks	82·3	89·5	87·0	90·1	±4·34	—	—	—	87·2±2·17	*	*
10 weeks	89·0	84·7±1·19	89·7	93·5	±0·99	—	**	**	89·2±0·50		
Calcium:											
4 weeks	87·8	95·3	92·9	96·7	±3·43	—	—	—	93·2±1·72		
7 weeks	79·1	85·3	80·0	87·1	±3·47	—	—	—	83·1±1·74	**	**
10 weeks	84·5	79·0±1·75	82·6	90·6	±1·46	—	**	**	84·2±0·73		

* Significant at $0{\cdot}01 < P < 0{\cdot}05$. ** Significant at $0{\cdot}001 < P < 0{\cdot}01$. *** Significant at $P < 0{\cdot}001$.

† Replacement value for the fourth calf calculated by the missing plot technique of Yates (1933).

Table 4. *Effect of chlortetracycline and iron supplementation, and the effect of age, on nitrogen retention of calves given large volumes of whole milk*

(Mean values with their standard errors)

	Treatment no. and details					Significance of main effects and interaction				Significance of difference between weeks		
	1 Control	2 Chlortetracycline	3 Fe	4 Chlortetracycline + Fe	Pooled SE of mean	Chlortetracycline	Fe	Interaction	General mean with its SE	4 *v.* 7	4 *v.* 10	7 *v.* 10
No. of calves:												
4 weeks	4	4	4	4	—	—	—	—	—	—	—	—
7 weeks	2	2	2	2	—	—	—	—	—	—	—	—
10 weeks	4	3†	4	4	—	—	—	—	—	—	—	—
Metabolic body size ($W^{0.73}$) (kg):												
4 weeks	16·8	18·8	18·5	18·8	±0·92	—	—	—	18·2 ± 0·46	—	—	—
7 weeks	22·9	22·0	23·8	23·2	±0·85	—	—	—	22·9 ± 0·42	—	—	—
10 weeks	24·8	27·0 ± 1·37	26·9	28·0	±1·14	—	—	—	26·7 ± 0·57	—	—	—
Live-weight gain (kg/day):												
4 weeks	0·64	0·89	0·79	0·96	±0·107	—	—	—	0·81 ± 0·053	—	—	—
7 weeks	0·66	0·86	0·91	0·77	±0·194	—	—	—	0·80 ± 0·097	—	—	—
10 weeks	0·86	0·83 ± 0·081	0·81	0·89	±0·067	—	—	—	0·84 ± 0·034	—	—	—
N intake (g/day):												
4 weeks	39·6	47·0	47·5	48·1	±3·11	—	—	—	45·6 ± 1·55	—	—	—
7 weeks	51·1	50·3	56·3	52·9	±4·22	—	—	—	52·6 ± 2·11	—	—	—
10 weeks	58·3	59·4 ± 3·46	63·0	64·4	±2·88	—	—	—	61·3 ± 1·44	—	—	—
Faecal N (g/day):												
4 weeks	2·5	1·4	2·5	1·7	±1·07	—	—	—	2·0 ± 0·53	—	—	—
7 weeks	3·4	3·3	3·1	3·9	±0·66	—	—	—	3·4 ± 0·33	—	—	—
10 weeks	1·9	3·4 ± 0·24	2·1	1·6	±0·20	*	**	**	2·3 ± 0·10	—	—	—

Urinary N (g/day):												
4 weeks	12·6	16·8	15·4	14·3	±1·61	—	—	—	14·8±0·80	**	***	***
7 weeks	24·4	21·9	24·6	22·8	±0·93	—	—	—	23·4±0·47			
10 weeks	27·4	30·1±1·57	29·8	30·0	±1·31	—	—	—	29·3±0·65			
N retention (g/day):												
4 weeks	24·5	28·8	29·7	32·1	±3·28	—	—	—	28·8±1·64	—	—	—
4 weeks (adjusted)‡	29·6±1·72	27·2±1·52	28·5±1·51	29·8±1·54	—	—	—	—	—	—	—	—
7 weeks	23·3	25·2	28·6	26·1	±4·82	—	—	—	25·8±2·41	—	—	—
7 weeks (adjusted)‡	24·8±1·16	27·3±1·18	24·7±1·26	26·4±1·14	—	—	—	—	—	—	—	—
10 weeks	29·0	25·9±2·30	31·0	32·8	±1·91	—	—	—	29·7±0·95	—	—	—
10 weeks (adjusted)‡	30·6±0·79	27·7±0·95	29·9±0·77	30·4±0·83	—	—	—	—	—	—	—	—
Biological value of milk protein:												
4 weeks	75·5	72·0	73·9	77·9	±3·32	—	—	—	74·8±1·66	**	***	—
7 weeks	58·9	63·5	63·9	63·9	±4·42	—	—	—	62·5±2·21			
10 weeks	61·3	56·7±1·49	61·1	62·3	±1·24	—	—	*	60·4±0·62			

* Significant at $0·01 < P < 0·05$. ** Significant at $0·001 < P < 0·01$. *** Significant at $P < 0·001$. *W*, body-weight.

† Replacement value for the fourth calf calculated by the missing plot technique of Yates (1933).

‡ Adjusted for differences between treatment groups in apparently digested N, by means of the following regression coefficients: 4 weeks, $0·79 \pm 0·133^{***}$; 7 weeks, $0·99 \pm 0·137^{*}$; 10 weeks, $0·62 \pm 0·093^{***}$.

Incidence of scouring and of a high rectal temperature. During the periods 0–14 days and 28–42 days the incidence of scouring was significantly reduced by chlortetracycline supplementation. During the latter period, the Fe supplement also reduced the incidence of scouring and there was an interaction between the two supplements owing to the increased effect when both supplements were given. The incidence of a high rectal temperature (> 102·8° F) in the period 0–14 days did not differ between treatments.

Milk consumption and refusals. Milk consumption was significantly greater for the calves given chlortetracycline in each of the 14-day periods up to the 56th day. Milk refusals tended to be greatest in the control calves and least for the calves in treatment 4 up to this age, but thereafter calves in treatment 2 (chlortetracycline alone) tended to have the greatest milk refusals.

Live-weight gain. Although the first Fe injection was not given until 7 days of age, both Fe and chlortetracycline increased live-weight gain during the period 0–14 days. After adjustment of live-weight gain, the effect of Fe supplementation and the interaction between Fe and chlortetracycline were significant. In each of the 14-day periods up to the 56th day, chlortetracycline supplementation increased live-weight gain, but after adjustment there were no treatment differences. Fe supplementation significantly increased weight gain, both before and after adjustment, in the period 56–70 days and not quite significantly in the period 70–84 days.

Digestibility of whole milk and N balance of the calves

Digestibility. The results are given in Table 3. The dry-matter content of the faeces was significantly greater at 10 weeks than at 4 weeks. At 4 and 7 weeks, the supplements had no effect on digestibility, but at 10 weeks of age Fe supplementation significantly increased and chlortetracycline supplementation significantly reduced digestibility of dry matter, fat and protein. The interaction between the two supplements was significant. Lactose digestibility was unaffected by treatment.

The apparent absorption of ash and calcium declined significantly from 4 to 7 and from 4 to 10 weeks. Apparent absorptions of ash and calcium at 10 weeks were significantly increased by Fe supplementation and, mainly because of the high extent of absorption when both supplements were added, there was a significant interaction between Fe and chlortetracycline.

N balance. The results are given in Table 4. Supplementation with Fe or chlortetracycline had no effect on any of the observed N values except that for the faecal N at 10 weeks. When the main effects were analysed, Fe supplementation significantly reduced and chlortetracycline supplementation significantly increased faecal N, the interaction between the two supplements being significant mainly because of the low faecal N value when both supplements were given. A significant interaction occurred between the two supplements in their effect on the biological value at 10 weeks of age owing to the low value when chlortetracycline was given alone. Moreover, after adjustment of N retention values for differences between treatment groups in mean apparently digested N, the chlortetracycline supplement given alone significantly

reduced ($P < 0.05$) N retention compared with that obtained when no supplement was given (treatment 1).

Urinary N excretion increased significantly with age, and the percentage of the ingested N that was retained decreased from 63·2 % at 4 weeks to 48·5 % at 10 weeks. This decrease was reflected in a decline in biological value of the protein from a general mean of 75 at 4 weeks to 60 at 10 weeks, in very similar N-balance values at the three ages in spite of the daily N intake increasing from 46 g at 4 weeks to 61 g at 10 weeks, and in similar weight gains at the three ages.

The relationships between apparently digested N and N balance for the three ages are given in Fig. 2.

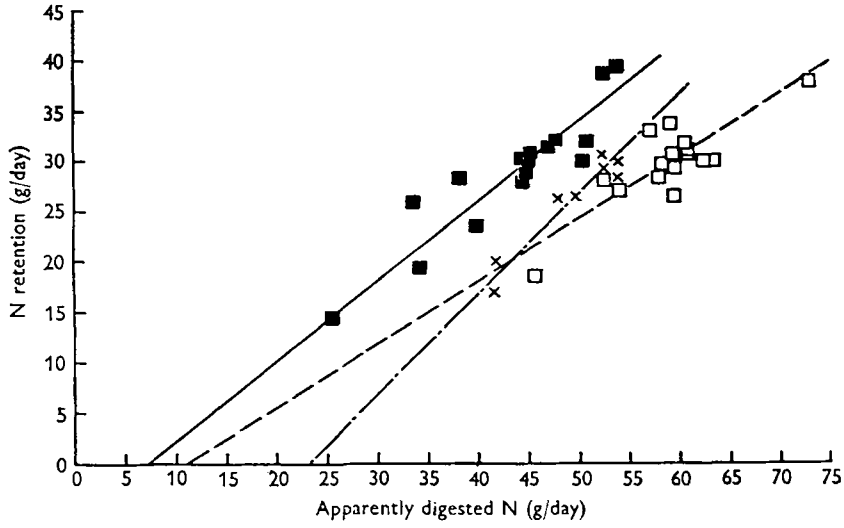

Fig. 2. Effect of age on the relationship between nitrogen retention and apparently digested N in calves. ■—■, 4 weeks; ×–·–×, 7 weeks; □ – – □, 10 weeks.

Endogenous urinary N was calculated from the relationship between the daily excretion of urinary N (UN) and daily intake of apparently digested N (ADN) at 4 weeks of age; N intake was clearly more limiting at this age than at 7 or 10 weeks. The equation was:

$$UN = 14{\cdot}8 + 0{\cdot}262(ADN - 43{\cdot}6).$$

When ADN is zero, the value for UN, which is then an estimate of the daily output of endogenous N, is 62·9 mg/kg live weight (W) or 184·4 mg/kg $W^{0{\cdot}73}$. The value was used in the calculation of biological value. It was considered that the calculated output of endogenous N would be similar at 7 and 10 weeks of age, as Stobo & Roy (1964) had found a value of 189 mg/kg $W^{0{\cdot}73}$ per day for ruminant calves at 12–18 weeks of age.

It was intended to use the mean of the metabolic faecal N values of Blaxter & Wood (1951*a*) and Cunningham & Brisson (1957), namely 0·392 g/100 g dry matter ingested, in the calculation of the biological values. As metabolic faecal N calculated from this

Table 5. *Effect of chlortetracycline and iron supplementation on the haematological picture of calves given large volumes of whole milk (first 84 days of life)*

	Treatment no. and details					
	1 Control	2 Chlortetracycline	3 Fe	4 Chlortetracycline + Fe	SD	Significance of difference between treatments†
No. of calves	6	7	7	6	—	—
Packed cell volume:						
Value at birth (%)	42·2	41·6	38·3	43·0	—	—
Change with age (%/day)	−0·26	−0·25	−0·13	−0·17	±0·055	1+2 > 3+4***
Haemoglobin:						
Value at birth (g/100 ml)	12·1	11·9	11·0	12·5	—	—
Change with age (g/100 ml day)	−0·082	−0·079	−0·033	−0·054	±0·0192	1+2 > 3+4***
Erythrocyte count:						
Value at birth (10^{-6}/mm^3)	7·4	8·0	6·3	7·4	—	—
Change with age (10^{-6}/mm^3 day)	−0·025	−0·015	−0·011	−0·013	±0·0170	—
Mean corpuscular volume:						
Value at birth (μm^3)	57·3	52·8	61·5	58·1	—	—
Change with age (μm^3/day)	−0·25	−0·28	−0·12	−0·18	±0·101	1+2 > 3+4**
Mean corpuscular haemoglobin concentration:						
Value at birth (%)	28·7	28·6	28·5	29·1	—	—
Change with age (%/day)	−0·034	−0·032	+0·018	−0·015	±0·033	1+2 > 3+4*
Erythrocyte sedimentation rate:						
Value at birth (mm/24 h)	2·2	2·3	2·4	2·2	—	—
Daily change with age (mm/24 h)	+0·046	+0·035	+0·021	+0·030	±0·0185	—
Total leucocyte count:						
Value at birth (10^{-3}/mm^3)	7·4	8·6	7·3	7·6	—	—
Change with age (10^{-3}/mm^3 day)	−0·052	−0·032	−0·021	−0·020	±0·0176	1+2 > 3+4**
Band neutrophils as % of total leucocyte count:						
Mean value during first 84 days of life‡	0·72	0·81	0·87	0·80	±0·069	1+2 < 3+4*
Change with age/day‡	+0·0002	−0·0017	+0·0002	+0·0009	±0·00270	—

Adult neutrophils as % of total leucocyte count:						
Value at birth	60·4	57·1	59·3	57·8	—	—
Change with age/day	−0·48	−0·37	−0·34	−0·35	±0·108	—
Lymphocytes as % of total leucocyte count:						
Value at birth	39·6	42·1	40·5	41·5	—	—
Change with age/day	+0·47	+0·37	+0·33	+0·31	±0·113	1+2 > 3+4*
Monocytes as % of total leucocyte count:						
Mean value during first 84 days of life‡	0·91	0·81	0·77	0·78	±0·110	1+2 > 3+4* 1 > 3* 1 > 4*
Change with age/day‡	+0·0024	+0·0010	−0·0005	−0·0012	±0·00285	1+2 > 3+4*
Eosinophils as % of total leucocyte count:						
Mean value during first 84 days of life‡	0·81	0·86	0·90	1·06	±0·156	1+2 < 3+4* 1 < 4**
Change with age/day‡	+0·0019	+0·0023	+0·0051	+0·0088	±0·00490	1+2 < 3+4*
Platelet count:						
Value at birth (10^{-3}/mm^3)	338	365	243	304	—	—
Change with age (10^{-3}/mm^3 day)	+0·58	+1·84	−0·16	−0·35	±1·421	1+2 > 3+4*
Blood urea content:						
Value at birth (mg/100 ml)	39·2	47·6	41·9	48·1	—	—
Change with age (mg/100 ml day)	+0·12	+0·14	+0·32	+0·15	±0·283	—

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

† Two treatment nos. joined by a plus sign indicates the mean value of those treatments.

‡ Values transformed thus $\sqrt{(x+\frac{1}{2})}$.

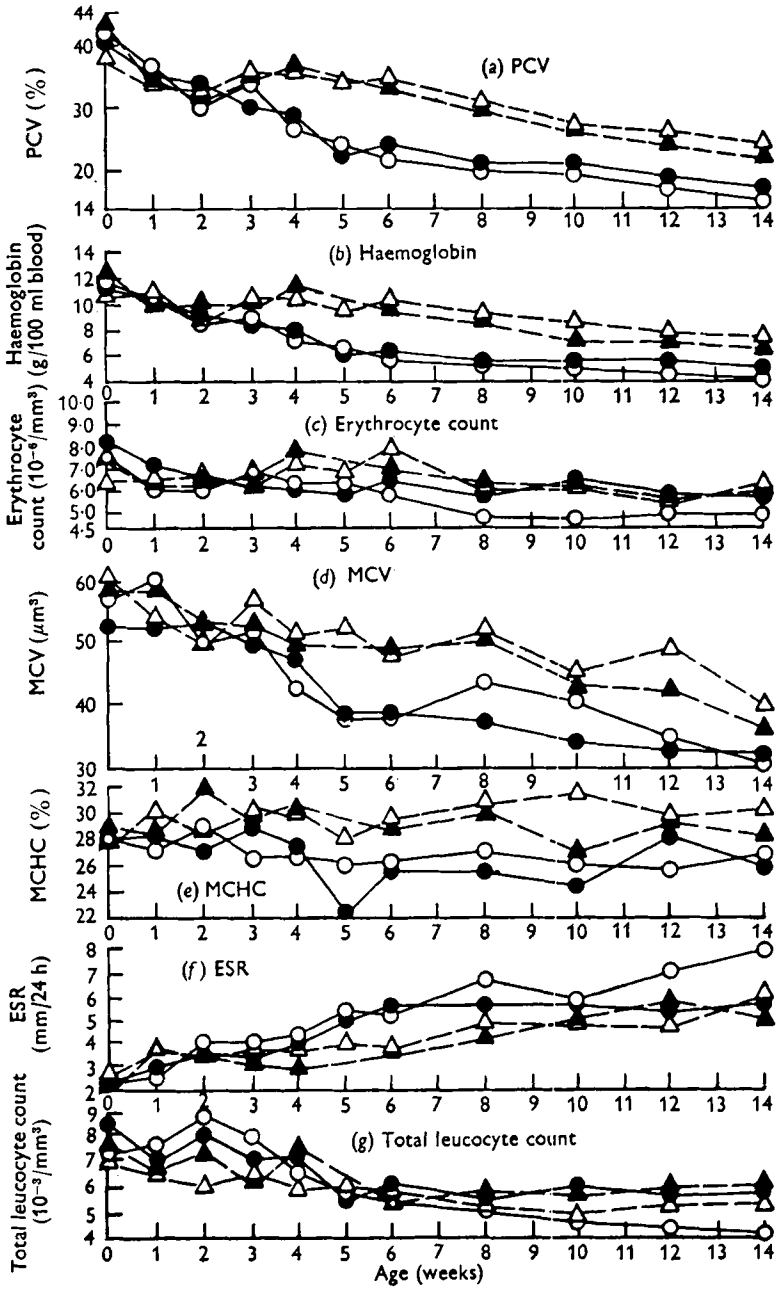

Fig. 3. Effect of chlortetracycline and iron supplementation on the haematological picture of calves given large volumes of whole milk. ○—○, control; ●—●, chlortetracycline; △---△, Fe; ▲---▲, chlortetracycline + Fe.

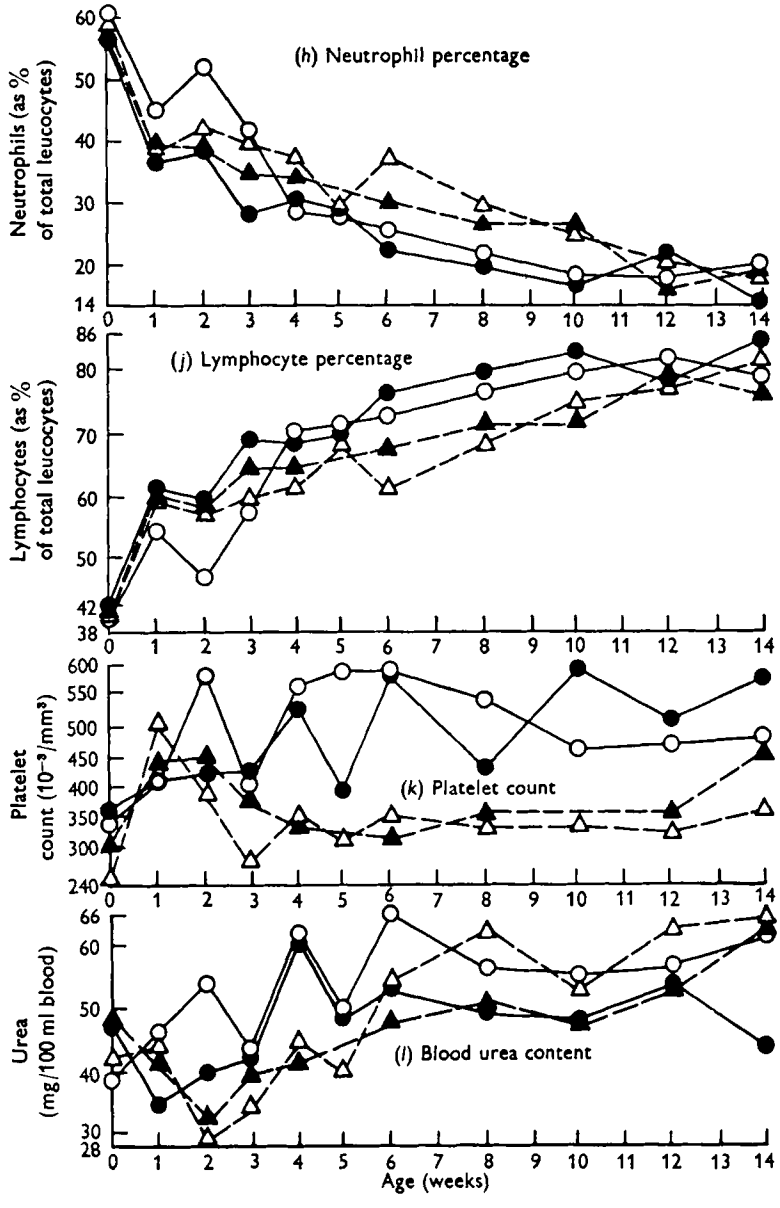

Fig. 3 (*cont.*). For legend see opposite page.

value was considerably greater than total faecal N, it was clear that the value was not applicable to calves reared on whole milk at very high levels of feeding. It was therefore assumed that the N of whole milk was 100% truly digested, and the mean faecal N value for all the calves, namely 0·191 g/100 g dry-matter intake, was used as an estimate of metabolic faecal N in the calculation of the biological values.

Haematological measurements

The results are given in Table 5 and Fig. 3. The results for two calves in the first block of the experiment, one in treatment 1 and the other in treatment 4, that had been reared on unprotected expanded-metal floors were excluded from the results, as it was clear that the floors had had a marked effect on their Fe intake as was evidenced by the colour of their faeces and by the haematological results. No such effect appeared to occur when calves had only unprotected iron bucket rings. Fe supplementation, but not chlortetracycline supplementation, had a pronounced effect on the haematological values of the calves.

Fe supplementation had a significant effect in reducing the rate of decline with age of PCV, haemoglobin content, MCV, MCHC, and total leucocyte count but had no significant effect on the decline in erythrocyte count with age. ESR increased from birth, those calves given Fe showing a smaller increase with age than those given no Fe, but the difference was not quite significant at the 5 % level. The mean percentages of band neutrophils and eosinophils present in samples during the first 12 weeks of life were significantly greater for the calves given the Fe supplement, whereas the mean percentage of monocytes was significantly less. There was no significant difference between treatments in the change in mean percentage of band neutrophils with age. The percentage of monocytes and the platelet count decreased with age in the calves given Fe and increased in the calves given no supplement, the difference being significant. However, the percentage of eosinophils increased with age in all treatments, the increase being significantly greater for the calves given the Fe supplement. During the first 2 weeks of life blood urea values fell in calves in all treatments except treatment 1. Thereafter values increased markedly up to 6 weeks of age, and then tended to increase at a slower rate. Fe supplementation had no effect but calves given the chlortetracycline supplement appeared to have lower values between 6 and 12 weeks.

Measurements made after slaughter

Partition of live weight. The results are given in Table 6. The difficulty of achieving 115 kg live weight in treatments 1 and 2 is reflected in the lower mean slaughter weight and dressed carcass weight for these calves. The mean slaughter weight values for all the treatments were below 115 kg owing to the fact that calves were fasted before slaughter.

Contents of the alimentary tract. The results are given in Table 7. All the calves, irrespective of treatment, had a large amount of hair in the reticulo-rumen. The hair was in the form of either a number of small hair balls (up to a total fresh weight of 1023 g) or one very large hair ball varying between 295 and 920 g fresh weight. The unexpectedly high proportion of the total contents of the alimentary tract present in the reticulo-rumen was a reflection of this finding. The reticulo-rumen of one calf in treatment 2 contained a large amount of milk and had markedly developed papillas; the results for this calf are not included in the values for alimentary tract contents. As would be expected from the results so far given, Fe supplementation significantly

Table 6. *Effect of chlortetracycline and iron supplementation on partition of live weight at slaughter of calves given large volumes of whole milk*

	Treatment no. and details			
	1 Control	2 Chlortetracycline	3 Fe	4 Chlortetracycline + Fe
No. of calves	7	7	7	7
Weight at slaughter (kg) A	108·5	104·2	112·0	113·9
Dressed carcass weight (kg) B	64·4	60·8	66·2	67·1
Killing out %, 100 B/A	59·4	58·2	59·0	59·1
Mean weight of skin: kg	8·8	7·7	9·2	8·8
As % of live weight	8·1	7·3	8·2	7·8
Mean weight of alimentary tract and contents: kg	11·8	13·1	11·8	12·4
As % of live weight	10·9	12·7	10·6	10·9
Mean weight of pluck: kg*	6·1	5·5	5·7	6·0
As % of live weight	5·6	5·3	5·1	5·3
Mean weight of head, legs and blood (by difference): kg	15·7	15·5	17·4	17·6
As % of live weight	14·5	14·8	15·5	15·5

* Lungs, heart, liver and spleen.

increased empty body weight. Chlortetracycline supplementation significantly increased the fresh weight of the reticulo-rumen. There was no relationship between the weights of any of the stomachs and empty body weight.

Vitamin A content of the liver and Fe content of the liver and pectoral muscle. The results are given in Table 8. The weights of livers of calves given additional Fe were very much lower than those of calves given none. Concentration and total content of vitamin A in the liver did not differ between treatments. Fe supplementation had a very marked effect on the Fe concentration and total content in the liver, but no significant effect on the Fe concentration in the pectoral muscle.

Estimate of the vitamin A requirement of calves given large volumes of whole milk and the effect of chlortetracycline supplementation on this estimate

The results are given in Table 9. The liver reserves at birth were estimated from the mean values obtained for calves born in the Institute herd from dams given normal and high-carotene diets (Walker, Thompson, Bartlett & Kon, 1949). Total vitamin A and carotene intakes of the final four blocks of calves in the experiment were calculated. After subtraction of values for the liver reserves of carotene at slaughter from those for carotene intake, the vitamin A equivalent of the carotene intake was obtained, 5 μg carotene being considered to be the equivalent of 1 μg vitamin A. This value was based on the results of Grifo, Rousseau, Eaton & Gosslee (1960) who found that 3·8 μg carotene were needed to obtain the same response as 1 μg vitamin A at an intake of 88 μg carotene/kg body-weight and 6·8 μg carotene at an intake of 353 μg/kg body-weight. Total vitamin A 'requirement', i.e. the amount of the vitamin utilized or excreted, was obtained by subtraction of the sum of the total vitamin A content

Table 7. *Effect of chlortetracycline and iron supplementation on the contents (mean values) and empty weights (mean values with their standard errors) of the digestive tract at slaughter of calves given large volumes of whole milk*

	Treatment no. and details					
	1 Control	2 Chlortetracycline	3 Fe	4 Chlortetracycline + Fe	Pooled SE of mean	Significance of difference between treatments
No. of calves	7	6†	7	6‡	—	—
Live weight (kg)	108·5	106·1	112·0	114·5	—	—
Total contents of alimentary tract:						
g	3609	4662	4125	3447	—	—
As % of live weight	3·35	4·42	3·69	3·00	—	—
% of total contents in:						
Reticulo-rumen	32·7	37·4	37·6	36·2	—	—
Omasum	0·4	0·5	0·4	0·4	—	—
Abomasum	22·9	16·0	14·5	14·3	—	—
Intestine	44·1	46·2	47·6	49·1	—	—
Empty body weight (kg)	104·9	98·6	107·9	112·0 ± 33·4‡	± 30·2	3+4 > 1+2*
Fresh weight of tissue (g):						
Reticulo-rumen	829	952	778	982 ± 77·4‡	± 70·0	2+4 > 1+3*
Omasum	242	242	271	264 ± 22·6‡	± 20·5	—
Abomasum	719	668	803	813 ± 96·1‡	± 86·9	—
Intestine	5547	5041	5054	5519 ± 278·3‡	± 251·7	—

* Significant at $0{\cdot}01 < P < 0{\cdot}05$.

† Values for one calf, whose total content of alimentary tract was 11 128 g as a result of the reticulo-rumen containing a large volume of milk, have been excluded from the data on contents.

‡ No measurements made on one calf.

Table 8. *Effect of chlortetracycline and iron supplementation on the vitamin A and iron content of the liver and on the iron content of the pectoral muscle of calves given large volumes of whole milk*

	Treatment no. and details					Significance of difference between treatment effects		
	1 Control	2 Chlortetracycline	3 Fe	4 Chlortetracycline + Fe	Pooled SE of mean	Chlortetracycline	Fe	Interaction
No. of calves	7	7	7	7	—	—	—	—
Live weight at slaughter (kg)	108·5	104·2	112·0	113·9	±2·84	—	*	—
Age at slaughter (days)	117	102	102	96	±5·7	—	—	—
Liver weight (g)	2770	2524	2201	2362	±108·6	—	**	—
Vitamin A concentration in liver (μg/g)	12·8	14·8	15·8	15·1	±1·99	—	—	—
Total vitamin A in liver (mg)	36·05	36·93	34·59	35·78	±4·383	—	—	—
Fe concentration in liver (μg/g)	10	15	21	23	±2·5	—	**	—
Total Fe in liver (mg)	28·76	35·97	45·45	54·21	±6·358	—	*	—
Fe concentration in pectoral muscle (μg/g)	6	8	7	9	±0·9	—	—	—

* Significant at $0{\cdot}01 < P < 0{\cdot}05$. ** Significant at $0{\cdot}001 < P < 0{\cdot}01$.

Table 9. *Effect of chlortetracycline and iron supplementation on the vitamin A 'requirement' of calves given large volumes of whole milk*

	Treatment no. and details				Significance of difference between treatment effects	
	1	2	3	4		
	Control	Chlortetracycline	Fe	Chlortetracycline + Fe	Chlortetracycline	Fe
No. of calves	4	4	4	4	—	—
Estimated liver vitamin A at birth (mg) (*a*)†	0·803	0·803	0·803	0·803	—	—
Total vitamin A intake from birth to slaughter (mg) (*b*)	358·460	271·920	306·412	255·724	—	—
Total carotene intake from birth to slaughter (mg) (*c*)	281·650	211·401	237·894	196·796	—	—
Total carotene in liver at slaughter (mg) (*d*)	2·261 (range 0–5·545)	1·298 (range 0–2·314)	0·876 (range 0–1·159)	0·925 (range 0–1·828)	—	—
Vitamin A equivalent of carotene intake less that stored in liver (mg) $\frac{1}{6}(c-d)$	55·878	42·021	47·404	39·174	—	—
Total vitamin A in liver at slaughter (mg) (*e*)	38·183	47·547	38·190	40·225	—	—
Total vitamin A 'requirement' (mg) $(a+b+\frac{1}{6}(c-d)-e)$	376·959	267·197	316·429	255·476	—	—
Age to slaughter (days)	128	101	109	96	—	—
Mean live weight (kg)	71·7	72·8	74·2	75·6	—	—
Live-weight gain/day (kg)	0·65	0·74	0·78	0·95	—	—
Daily vitamin A 'requirement':						
mg	2·948	2·676	2·937	2·810	—	—
μg/kg live weight	41 ± 1·2	37 ± 1·2	40 ± 1·2	38 ± 1·2	•	—
μg per kg daily weight gain per kg live weight	64 ± 4·2	51 ± 4·2	52 ± 4·2	40 ± 4·2	•	•

• Significant at $0{\cdot}01 < P < 0{\cdot}05$.

† Estimated from the mean liver reserves at birth of calves born of cows given normal or high-carotene diets (Walker *et al.* 1949).

of the liver at slaughter and the estimated content at birth from the sum of the vitamin A intake and the vitamin A equivalent of the carotene intake. By this method, daily vitamin A requirement was estimated as about 40 μg/kg live weight. Chlortetracycline supplementation significantly reduced this requirement. When calculated on the basis of μg vitamin A per kg daily weight gain per kg live weight, both chlortetracycline and Fe supplementation significantly reduced the 'requirement'.

DISCUSSION

Weight gain and incidence of scouring

The findings in this experiment show clearly that supplementation with both Fe and chlortetracycline has a very marked effect on the performance of calves given large volumes of whole milk.

In an earlier experiment (Roy, Shillam, Palmer & Ingram, 1955), chlortetracycline supplementation significantly reduced the incidence of scouring during the first 3 weeks of life of calves restricted to a liquid diet. Similar results were obtained in the experiment now described. Chlortetracycline supplementation significantly reduced the incidence of scouring during the first 12 weeks of life, particularly during the first 2 weeks and from 4 to 6 weeks. This effect was reflected in increased weight gains during fortnightly periods up to 8 weeks. As weight gain adjusted for initial weight and milk consumption during these periods was on no occasion significantly affected by chlortetracycline supplementation, it is apparent that the effect of chlortetracycline was largely dependent on the greater milk intake in the calves given chlortetracycline as a result of the reduced incidence of scouring.

Fe supplementation significantly increased weight gain during the first 12 weeks of life, whether or not the calves had iron fittings in their pens. The significant effect of Fe supplementation on weight gain, even when adjusted, during the first 14 days of life was unexpected, as the first injection was given at 7 days of age. However, in view of the findings by Blaxter *et al.* (1957) that in the north of Scotland there was a marked difference between farms in haemoglobin levels of calves, and by Hibbs *et al.* (1961) in Ohio that 30 % of calves had haemoglobin levels of less than 9 g/100 ml at birth, it seemed possible that our finding might be a reflection of low haemoglobin values at birth. Analyses of blood samples collected during the period December 1960–May 1962 from fifty-six calves before suckling showed that the mean haemoglobin content varied widely between the nine Ayrshire and two Shorthorn herds involved. The lowest mean value for an Ayrshire herd was 10·7 g/100 ml (range 9·4–12·1) and the highest 14·1 g/100 ml (range 11·5–16·8). Each of the two lowest mean haemoglobin values for Ayrshire herds differed significantly from the three highest mean values. It was of some interest that the two herds with the lowest mean haemoglobin values were in adjacent farms. As the mean haemoglobin content at birth of the calves in our experiment was 11·9 g/100 ml, it seems possible that Fe supplementation may have had a beneficial effect during the first 2 weeks of life, in spite of the failure of Hibbs *et al.* (1961) to obtain a response from the injection of 500 mg Fe dextran in their calves. The increase in blood urea values of the calves in treatment 1 during the first 14 days

of life compared with a fall in values for calves in the other treatments is paralleled by the lower weight gain of calves in treatment 1 during this period. This high blood urea level could be associated with a reduced level of hydration in the calves in treatment 1, as has been observed in the newborn infant (McCance & Widdowson, 1947).

As well as its effect in the first 14 days of life, Fe supplementation reduced the incidence of scouring from 4 to 6 weeks of age, and increased weight gain from 8 weeks of age onwards, although the increase in the period from 10 to 12 weeks was not quite significant. Thus, the beneficial effect of Fe supplementation appears mainly to exert its influence when haemoglobin values have fallen below 7 g/100 ml, a value that was observed with the calves given no Fe supplement between 4 and 5 weeks of age, but was not reached in the calves given Fe until the 14th week. As adjusted weight gain to 12 weeks did not differ significantly between treatments, it is clear that up to this time one of the main nutritional benefits of Fe supplementation is to reduce the anorexia associated with anaemia; milk refusals were three to four times greater by the calves deprived of supplementary Fe.

Digestibility of whole milk and N metabolism of the calves

Besides this effect on appetite, Fe supplementation had a beneficial effect on the utilization of whole milk at 10 weeks of age in increasing the digestibility or absorption of its constituents. On the other hand chlortetracycline had an adverse effect, unless the calf had received Fe at an earlier age.

The decline with age in the apparent absorption of calcium and ash has been observed by other workers and was reviewed by Roy (1959). The decline in apparent absorption of calcium from 93·2 % at 4 weeks to 84·2 % at 10 weeks was very much less than that observed by Smith (1957), who found a decline in calcium retention from 93·5 % at 2–5 weeks to 76·5 % at 7–9 weeks in calves given whole milk at a level of 4·4 kg/day. The smaller decline in our experiment was probably a reflection of the higher level of milk intake, since Blaxter & Wood (1952) have shown that the retention of calcium increases from 73 % at the maintenance level of intake to 92 % when the amount of milk is sufficient to give a daily weight gain of 0·90 kg. However, the very high percentage of apparent absorption of calcium by calves in treatment 4 cannot be accounted for by the level of intake, which was similar in all treatments. It could be partly accounted for by the increased digestibility of fat, and a concomitant decrease in faecal excretion of calcium as calcium soaps of fatty acids; possibly there is also a systemic effect of Fe in increasing calcium retention as a result of an increased oxygen supply to the tissues.

In spite of the increased digestibility of protein by the calves given the Fe supplement, no difference was discernible in N balance, probably because the protein intake at 10 weeks of age was excessive in relation to energy supply. Blaxter & Wood (1951*b*) showed that, for the 30 kg calf, it is only at daily weight gains of 0·80 kg or more that 21 % of the digestible energy is required as protein of 100 % biological value. By means of the equations given by these authors, it is possible to calculate the percentage of protein of 100 % biological value that should not be exceeded if deamination is to

be avoided, at the weight and weight gain of calves at 4, 7 and 10 weeks of age in our experiment. These percentages have been calculated with endogenous urinary N and digestible energy for maintenance related to live weight, and also to metabolic body-weight (kg $W^{0.73}$) and are presented in Table 10, together with the results we obtained for calves in treatment 4. The weight gain for the balance period has been taken as the mean for the 3-week period within which the balance occurred, as there is little doubt that weight gains tend to be depressed when calves are in metabolism crates. Although only the values for calves in treatment 4 are given, the percentage of protein that should not be exceeded if deamination is to be avoided was similar for all treatments. The percentages found by us are of the same order as those calculated from the results of Blaxter & Wood (1951*b*), using maintenance related directly to live weight. However, the digestible energy required and the N retentions observed were considerably higher in our experiment than those calculated from the values of Blaxter & Wood (1951*b*).

The 'available protein' (Blaxter & Mitchell, 1948) requirement of the 4-week-old calf (55·6 kg live weight) gaining weight at 940 g/day is thus 285 g, equivalent to 25·7 % of the digestible energy. If the biological value of the diet could be maintained at 78 at 7 and 10 weeks of age by inclusion of more energy relative to protein, then the percentage of digestible energy as available protein that would not have to be exceeded if deamination were to be avoided would be 19·5 and 19·8 % at 7 and 10 weeks of age respectively.

The value of 62·9 mg/kg body-weight for endogenous urinary N found by us can be compared with our earlier value of 64·4 mg during the first 10 days of life (Shillam & Roy, 1963) and the values of 65·3 mg obtained by Cunningham & Brisson (1957) and 81·9 mg found by Blaxter & Wood (1951*a*).

The value used by us for metabolic faecal N, namely 0·191 g/100 g dry matter ingested, which assumed a true digestibility of milk protein of 100 % is more in keeping with the value of 0·27 g/100 g dry matter ingested, obtained by Lofgreen & Kleiber (1953), who found a true digestibility of casein of 93·5 %, than with the unexpectedly high value of 0·43 g/100 g dry matter ingested found by Blaxter & Wood (1951*a*) and the value of 0·33 g/100 g dry matter ingested (Cunningham & Brisson, 1957). It would seem that the synthetic diets used by the latter workers may well have been responsible for their high values.

The marked fall in biological value from 4 to 7 weeks and the smaller fall from 7 to 10 weeks, associated with the increased urinary N excretion, is clearly reflected in the blood urea values which increased rapidly from 2 to 7 weeks and then levelled off.

As it is doubtful if milk intake could have been greatly increased it would seem that to obtain maximum performance with liquid-fed calves after 7 weeks of age the diet would have to contain considerably more energy relative to protein than is present in whole milk.

The mean quantities of N retained at 4, 7 and 10 weeks in treatment 4 were 3·41, 2·87 and 3·31 g/100 g weight gain respectively, which are in general higher than the values of 2·62 g obtained by Blaxter & Wood (1951*b*) and of 3·22 g by Brisson, Cunningham & Haskell (1957) with milk-fed animals. The results of Moulton, Trowbridge & Haigh reported by Armsby & Moulton (1925) showed that the N content of

Table 10. *Comparison of the net protein and digestible energy requirements of calves in treatment 4 with the values for similar calves calculated from the data of Blaxter & Wood (1951 b)*

Weight of calf (kg)	Daily gain in weight* (g)	Age (weeks)	Source	N retention (g/day)	Endogenous N (g/day)	Net protein required by tissues (g/day)	Digestible energy required (kcal)	% of digestible energy needed as protein to avoid deamination
55·6	940	4	This experiment	32·1	3·47†	222·3	6265‡	20·0
			Blaxter & Wood§	25·3	4·45	185·9	5799	18·1
			Blaxter & Wood‖	25·3	3·91	182·6	5268	19·5
74·0	910	7	This experiment	26·1	4·28†	189·9	7025‡	15·2
			Blaxter & Wood§	24·6	5·92	190·8	6672	16·1
			Blaxter & Wood‖	24·6	4·82	183·9	5733	18·1
96·0	990	10	This experiment	32·8	5·16†	237·3	8702‡	15·4
			Blaxter & Wood§	26·6	7·68	214·3	8069	15·0
			Blaxter & Wood‖	26·6	5·82	202·6	6587	17·3

* Mean of daily weight gain during the 3-week period within which the balance was made.
† Calculation based on 184·4 mg/kg live weight$^{0·73}$ for endogenous N.
‡ 5·68, 5·54 and 5·68 kcal digestible energy/g dry matter at 4, 7 and 10 weeks respectively.
§ Calculation based on 80 mg/kg live weight for endogenous N and 52·4 kcal/kg for digestible energy at maintenance (Blaxter & Wood, 1951 *b*).
‖ Calculation based on 207·9 mg/kg live weight$^{0·73}$ for endogenous N and 126·7 kcal/kg$^{0·73}$ for digestible energy at maintenance (based on Blaxter & Wood 1951 *b*).

calves increased from 2·8% of empty body weight at birth to 3·2% at 3 months. Thus, the mean content of N retained during this period would need to be greater than 3·2% to cause an increase from 2·8 to 3·2% in N content.

It was abundantly clear that the level of energy intake in our experiment, namely 236 kcal gross energy, was too low to achieve 100 g gain in weight. The value was based on the results with newborn calves gaining weight at up to 454 g/day (Roy *et al.* 1958) and is considerably lower than that suggested by Blaxter & Wood (1951*b*) and Brisson *et al.* (1957), namely 307 kcal and 268 kcal digested energy/100 g gain respectively. If the maintenance requirement of 52·4 kcal digested energy/kg live weight (Blaxter & Wood, 1951*b*) is assumed to be correct, then calves in treatments 1–4 required 335, 312, 310 and 302 kcal digested energy/100 g gain respectively up to 84 days of age. These values suggest that both the supplements were having a beneficial effect in reducing the energy requirements but the differences were not quite significant. It will be noted that the overall value of 302 kcal digested energy/100 g gain in treatment 4 was considerably less than the values calculated from the digestible energy intake during the balance periods, which were 357, 346 and 371 kcal/100 g gain at 4, 7 and 10 weeks respectively. This finding may have been related to the increased heat losses by the calves when in the metabolism crates. As the mean exogenous urinary N excretion in treatment 4 was estimated as 15·8 g/day, of which about 83% would be urea N (Blaxter & Wood, 1951*a*), there was a further mean loss of energy in the urine of 71 kcal/day giving a metabolizable energy value of about 295 kcal/100 g gain.

Haematological findings

The haematological findings suggest that, provided haemoglobin levels are maintained above 7 g/100 ml, good performance may be achieved. With piglets, no difference in performance has been observed between those with haemoglobin levels that fell to 8 g/100 ml and those in which haemoglobin levels were maintained at 11 g/100 ml (Barber, Braude, Clarke & Mitchell, 1958). According to Holman (1955, 1956) the term pathological anaemia should be applied to haemoglobin values below 8 g/100 ml, and anaemia can be classified as follows: mild anaemia 7 g/100 ml, moderate anaemia 5–6 g/100 ml, severe anaemia 4 g/100 ml and less.

Under this classification, it can be seen that calves given the Fe supplement were approaching a state of mild anaemia at 14 weeks, whereas calves given no supplement were moderately anaemic at 6 weeks and severely anaemic at 14 weeks.

The mean erythrocyte count, although declining with age, never fell so low as to be considered abnormal, namely below $4{\cdot}5 \times 10^6/mm^3$, but it was approaching this value for the control calves at 9 weeks of age. Fe supplementation had no effect on the decline in count with age, a finding in contrast to those of Herman (1936), Knoop *et al.* (1935) and Blaxter *et al.* (1957), who found that Fe supplementation prevented a fall in erythrocyte count. However, in those experiments the calves gained weight more slowly, and the fall in count did not occur until after 12 weeks of age, and in the experiments of Herman (1936) and Knoop *et al.* (1935) it was not very marked. In our experiment no regenerative changes such as the presence of reticulocytes, poly-

chromatic cells, punctate basophilia and erythroblasts, which have been shown to occur when the erythrocyte count is reduced to under $4 \times 10^6/mm^3$ (Wirth, 1950), were observed.

The decline in MCV paralleling the change in haemoglobin showed that the form of anaemia was microcytic. In the experiments of Blaxter *et al.* (1957), no decline in MCHC occurred, and they concluded that the anaemia was microcytic normochromic compared with the usual microcytic hypochromic anaemia in man. Holman (1956) suggests that a state of hypochromia exists when the MCHC falls below 24%, as did the mean value for the calves given the chlortetracycline supplement (treatment 2) at 5 weeks. Although by this criterion it is clear that the calves were not suffering in general from a hypochromic anaemia, nevertheless the erythrocytes of the calves given no Fe supplement were more hypochromic than those of calves given additional Fe, and individual calves, namely two in treatment 1 and one in treatment 2, showed a severe hypochromic anaemia. Thus, it would seem that, when certain calves became severely anaemic, the anaemia changed from a normochromic to a hypochromic microcytic form.

The increase of ESR with age has been demonstrated by us in an earlier experiment (Hawkins, Roy, Shillam, Greatorex & Ingram, 1959); the greater rise with the calves given no Fe, was probably a reflection of their anaemic state, since it is known that there is a tendency for an inverse relationship between ESR and erythrocyte count (Bell, Davidson & Scarborough, 1961).

In contrast to the finding of Blaxter *et al.* (1957), who found no effect of anaemia on the leucocyte count, in our experiment there was a greater degree of leucopenia with calves given no Fe, especially for those in treatment 1 whose mean count at 14 weeks approached the value of $4 \times 10^3/mm^3$, considered for clinical purposes to show a leucopenia. The higher percentage of band neutrophils in the blood of the calves given the Fe supplement suggests a higher production of neutrophils, which was reflected in the tendency for a smaller fall in the number of mature neutrophils with age in these calves. Several of the calves given no Fe showed an absolute neutropenia.

The increased lymphocytosis with age, the increased percentage of monocytes present during the first 12 weeks of life, and the increase in percentage of monocytes with age for the calves deprived of supplementary Fe, compared with a reduction in percentage of monocytes with age for those given Fe may all have been the result of an increased susceptibility to infection, possibly by *E. coli*.

The decrease in the percentage of eosinophils during the first 12 weeks and a decline in the rate of increase with age in the calves given no supplementary Fe, might have been expected from the findings of Schultze (1957) that faster-growing calves have higher eosinophil counts. He suggested that, as eosinophil numbers appeared to be inversely related to the amount of circulating adrenocortical hormones, a calf's inability to adjust itself to adverse conditions might be related to an increased release of these hormones.

The significantly greater increase in platelet count with age in the calves given no additional Fe is in contrast to the normal findings in man suffering from hypochromic anaemia, in whom platelet count is 'low normal' (Ogilvie, 1957).

The finding that chlortetracycline supplementation of the diet had no significant effect on the haematological picture of the calves confirms the findings of Owen *et al.* (1955) with calves allowed access to dry food.

Measurements made after slaughter

The measurements obtained after slaughter showed that the total weight of contents of the alimentary tract was 3·6% of the live weight, a value that may be compared with that of 4·1%, 8 h after the last feed, found at 7 days of age by Kesler, Ronning & Knodt (1951) and of 6·2%, 3 h after the last feed, observed by Stobo & Roy (1962, unpublished) at 21 days of age. Thus, in calves restricted to a liquid diet, the weight of contents of the alimentary tract, as a percentage of live weight, remains approximately constant to 13 weeks of age.

The reason for the increase in fresh weight of the reticulo-rumen of calves given the chlortetracycline supplement is not known, but Clegg (1962) has some evidence that antibiotic feeding, presumably of dry-fed animals, increases the volume of the reticulo-rumen.

Utilization of Fe

Fe supplementation had very little effect on the muscle Fe, in spite of the marked increase of total Fe in the liver. This finding was probably in part a reflection of the greater amount of blood trapped in the liver. However, the concentration of Fe in the livers of the calves given additional Fe in our experiment was less than the concentration found by Knoop *et al.* (1935), Blaxter *et al.* (1957) and Niedermeier *et al.* (1959) in the livers of calves given no supplement, namely about 30 μg Fe/g liver. The failure to draw on muscle Fe except under very severe anaemic conditions has been demonstrated in perfused rats, whose liver Fe was 21·3 and 9·3 g/100 g dry matter for normal and anaemic rats respectively but whose muscle Fe was 7·9 and 6·9 g/100 g dry matter (Austoni, Rabinovitch & Greenberg, 1940).

An estimate of utilization of the injected Fe is given in Table 11. In this calculation the same blood volume as percentage of live weight has been used for anaemic calves and those given supplementary Fe. However, it is well known that anaemia tends to reduce blood volume; if the blood volume had been 5% lower in the anaemic calves, the percentage utilization of the Fe dextran would have been 64. Moreover, it is well established that the absorption of dietary Fe is roughly proportional to body needs, and that, in anaemic man, rat and dog, absorption may be twice as high as in normal subjects (Hahn, Bale, Ross, Balfour & Whipple, 1943; Hahn, 1948). If the same is also true of calves, then the utilization of the injected Fe dextran would have been 70%. The calculation also ignores any fall in Fe content of the bone marrow, although it would include most of the Fe in cytochrome oxidase and catalase enzymes. However, Austoni *et al.* (1940) have shown that the bone marrow shows no decrease in Fe content until an animal is very severely anaemic, and cytochrome oxidase activity increases and catalase activity decreases in anaemic rats (Schultze, 1939; Schultze & Kuiken, 1941).

Table 11. *Estimation of the retention of 1500 mg Fe as Fe dextran injected from 1–3 weeks of age*

	Calves given no supplement		Calves given Fe supplement		Factors used in calculation
Live weight at slaughter (kg)	106·4		113·0		—
Blood volume (l.)	6·6		7·0		6·2 % of live weight (Hansard, Butler, Comar & Hobbs, 1953)
Haemoglobin content (g/100 ml)	4·4		6·9		—
Weight of haemoglobin (g)	290		483		—
Weight of Fe in haemoglobin (mg)		986		1642	Fe content of haemoglobin assumed to be 0·34 %
Weight of liver (g)	2647		2282		—
Fe content of liver (μg/g)	12·5		22·0		—
Weight of Fe in liver (mg)		33		50	—
Weight of spleen (g)	395		341		Assumed ratio of 6·7:1 for liver to spleen weight, which is the mean of the ratios from Knoop *et al.* (1935), Hawkins *et al.* (1959) and unpublished work
Fe content of spleen (μg/g)	41·3		72·6		Assumed ratio of 3·3:1 for spleen Fe content to liver Fe content, which is the mean of the ratios from Elvehjem & Peterson (1927) and Blaxter *et al.* (1957)
Weight of Fe in spleen (mg)		16		25	
Weight of lungs and heart (kg)	2·7		3·2		From difference between 'pluck weight' and liver and spleen weight
Fe content of lungs and heart (μg/g)	48		85		Value for supplemented calves based on value of Elvehjem & Peterson (1927). Value for unsupplemented calves obtained by using ratio of 1:1·76 for unsupplemented and supplemented calves as found for liver. The computed values are similar to those of Blaxter *et al.* (1957)
Weight of Fe in lungs and heart (mg)		130		272	
Weight of carcass + head + lower part of legs (kg)	71·3		76·9		—
Weight of muscle (kg)	47·1		50·8		Assumed to be 66 % of carcass weight
Weight of skin (kg)	8·3		9·0		—
Fe content of muscle (μg/g)	7		8		—
Weight of Fe in muscle and skin (mg)		388		478	Fe content of muscle and skin assumed to be the same
Weight of Fe in calves (mg)		1553		2467	—
Difference between calves with and without supplement (g)		0·914			—
Retention of 1·5 g Fe as Fe dextran (%)		60·9			—

The estimated value for the utilization of injected Fe dextran may be compared with the finding that only 70% of 30 mg labelled Fe as Fe dextran injected into pigs was retained 32 days after injection, whereas 95% of 180 mg injected was retained up to this time. Haemoglobin content was maintained at 8·8 g/100 ml by 180 mg Fe, whereas 30 mg Fe allowed haemoglobin to fall to 3·9 g/100 ml (Braude, Chamberlain, Kotarbińska & Mitchell, 1962). These authors suggest that with a dose insufficient to prevent anaemia the Fe given is not completely utilized and that some of it is excreted. In our experiment, excretion losses could thus possibly account in part for the low utilization, as there was a period of 96 days between the first injection and slaughter, during which haemoglobin levels were gradually falling. Moreover, if additional Cu had been given, the utilization values might have been increased. However, Matrone, Conley, Wise & Waugh (1957) were unable to show any effect of Cu supplements on the haemoglobin levels of anaemic or normal calves.

As injection of 1500 mg Fe increased haemoglobin content by 2·5 g/100 ml at the end of a period of 103 days, a total injection of 3360 mg Fe, the same utilization of Fe being assumed, would probably be required to maintain haemoglobin at 10 g/100 ml at that age. The calves also received about 938 kg milk containing about 0·4 mg Fe/l., or 375 mg total Fe. The total gross requirement of Fe administered by these methods would therefore be about 36 mg/day. If all the Fe had been given by mouth, and a utilization of 30% is assumed (Matrone *et al.* 1957), the gross requirement would be about 70 mg Fe/day, a value that compares with the suggested minimum requirement of 56 mg Fe/day for 227 kg calves gaining 0·91 kg/day (Matrone *et al.* 1957) and the requirement of 100 mg Fe/day for adequate liver storage by calves gaining 1·0 kg/day (Blaxter *et al.* 1957).

Niedermeier *et al.* (1959) suggested that the giving of 240 mg Fe/day to calves given a milk diet *ad lib.* had a depressing effect on liver vitamin A content; their group given no additional Fe had a liver vitamin A content of 9·5 μg/g at 39 days, whereas the group given the supplement had a value of 6·6 μg/g. In the results of our experiment there was no evidence that the Fe injections affected the liver reserves of vitamin A.

Estimated vitamin A requirements

The estimated vitamin A requirement of veal calves is clearly not a minimum requirement, but it is also certainly not the requirement for maximum liver storage. The mean liver storage of vitamin A at slaughter was only 14·6 μg/g, whereas Walker *et al.* (1949) obtained a mean value of 56·1 μg vitamin A/g in livers at birth of calves born to heifers given high levels of vitamin A prepartum, and Eaton, Rousseau, Dicks, Teichman & Grifo (1958) have obtained liver reserves at slaughter of up to a mean of 742 μg/g in nine animals, although the reserves of the remainder of their 125 calves in the weight range 69–268 kg did not exceed 79 μg/g. Unfortunately, no plasma vitamin A estimations were done by us. However, Eaton *et al.* (1958) found that the relationship between liver reserves and plasma vitamin A in their calves was:

$$Y = 9{\cdot}08x - 3{\cdot}7,$$

where Y = plasma vitamin A content in μg/100 ml and x = log liver concentration of vitamin A in μg/100 g.

From this equation, the plasma vitamin A at slaughter of the calves in our experiment would have been about 25·0 μg/100 ml. At the generally accepted level of depletion of 4·0 μg vitamin A/100 ml plasma, the liver reserves would have been 0·07 μg/g.

Thus in our experiment the intake per kg live weight of about 44 μg vitamin A daily, both preformed and from carotene, was adequate to maintain normal plasma values and small liver reserves, and is within the range of values obtained by Lewis & Wilson (1945), who suggested that for maximum growth rate 16 μg vitamin A/kg were required, for maximum plasma levels 128 μg/kg and for maximum liver reserves 256 μg/kg.

In conclusion, the findings of this experiment disclose the marked importance of Fe in the nutrition of the veal calf, the benefits obtained from chlortetracycline supplementation provided the calf is not anaemic, and the fact that a milk substitute similar in composition to whole milk would be unlikely to produce maximum growth rates after 7 weeks of age without the inclusion of an additional source of energy.

SUMMARY

1. Twenty-eight newborn Ayrshire bull calves were used to study the effect of inclusion of chlortetracycline (12 mg/kg) in a whole-milk diet and the effect of intramuscular injections of a total of 1500 mg iron as Fe dextran during the first 3 weeks of life on the performance and haematological picture of calves reared for veal production to 115 kg live weight.

2. Chlortetracycline significantly reduced the incidence of scouring in the first 12 weeks of life. Fe supplementation significantly increased weight gain to 12 weeks of age and to the time of slaughter, and reduced the time required for the calves to reach 100 kg live weight. The main effect of Fe supplementation was during the first 2 weeks of life and from 8 weeks onwards.

3. Chlortetracycline significantly depressed apparent digestibility of total solids, fat and protein at 10 weeks of age in calves given no Fe injections. Fe injections significantly increased apparent digestibility at 10 weeks of total solids, fat and protein, and apparent absorption of ash and calcium, which was further enhanced by chlortetracycline supplementation. Apparent absorption of ash and calcium declined from 4 to 10 weeks.

4. N retention was unaffected by treatment except that, after adjustment for differences between treatment groups in mean apparently digested N, N retention at 10 weeks was significantly lower for calves given the chlortetracycline supplement alone than for those given no supplement. The biological value of the protein of whole milk fell from 75 at 4 weeks to 60 at 10 weeks with a concomitant increase in blood urea values.

5. Daily endogenous urinary N excretion was estimated as 184·4 mg/kg body-weight$^{0.73}$. Metabolic faecal N appeared to be no greater than 0·191 g N/100 g dry matter ingested. Digestible energy required for 100 g gain in weight for calves given both supplements was 302 kcal.

6. Chlortetracycline supplementation had no effect on the haematological picture of the calves. Fe supplementation reduced the decline with age of packed cell volume,

haemoglobin content, mean corpuscular volume, mean corpuscular haemoglobin concentration and total leucocyte count. Fe supplementation reduced the increase with age of erythrocyte sedimentation rate, lymphocyte, monocyte and platelet counts. Fe supplementation increased the percentage of band neutrophils and eosinophils present and enhanced the increase of eosinophils with age. The erythrocyte count declined with age but was unaffected by Fe supplementation.

A study of the haemoglobin content of newborn Ayrshire calves before suckling showed a significant difference between farms.

7. Supplementation with Fe increased the concentration and total content of Fe in the liver, and reduced liver weight, but had no effect on muscle Fe.

8. The contents of the alimentary tract at slaughter were 3·6% of live weight. Chlortetracycline supplementation significantly increased the fresh empty weight of the reticulo-rumen.

9. Vitamin A requirement for normal plasma vitamin A and small liver reserves was estimated as 44 μg/kg live weight. Chlortetracycline supplementation significantly reduced this requirement.

10. The utilization of the injected Fe was estimated as between 60 and 70%. To maintain haemoglobin levels at 10 g/100 ml to 104 days of age, it was estimated that 3·4 g Fe as Fe dextran would need to be injected. The gross requirement for Fe so administered, including that present in the milk, would be about 36 mg Fe/day, or 70 mg Fe/day if all Fe was given by mouth.

11. From the N metabolism values, it is concluded that whole milk is deficient in energy for maximum production after 7 weeks of age.

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