Studies of the nutrition of the young calf

2.* The nutritive value of unhydrogenated palm oil, unhydrogenated palm-kernel oil, and butterfat, as additions to a milk diet

By A. M. RAVEN and K. L. ROBINSON

Chemical Research Division, Ministry of Agriculture for Northern Ireland and Agricultural Chemistry Department, Queen's University, Belfast

(*Received* 13 *September* 1958)

In an earlier investigation (Raven & Robinson, 1958), we found that an hydrogenated palm oil was very much inferior to butterfat as a source of energy for calves. This inferiority was partly due to a somewhat lower digestibility, but the main factor was the very poor utilization of the digested palm oil compared with that of butterfat, as judged by their respective protein-sparing effects.

One of the factors which may affect the digestibility of a fat is its melting point. Deuel (1948), however, has summarized the reported tests on man and noted that, of thirty-four vegetable fats melting below 50°, only two had digestibility coefficients below 95. Thus it seems unlikely that the melting point of the hydrogenated palm oil, which was 35°, could account for its lower digestibility as compared with that of butterfat.

The studies of Lambert, Jacobson, Allen & Zaletel (1954) have shown that the calf is susceptible to a deficiency of essential fatty acids. Thus the poorer digestibility and utilization of the hydrogenated palm oil may have been due to a dietary need for these acids, namely linoleic, linolenic and arachidonic acids. There appears to be little available information about the essential fatty-acid composition of hydrogenated palm oil, but it seems probable that it contains little or no linoleic acid, in contrast to the unhydrogenated oil. Aaes-Jørgensen (1954) has reported better growth of rats on unhydrogenated fats than on hydrogenated fats and together with other workers (Aaes-Jørgensen & Dam, 1954; Aaes-Jørgensen, Engel, Funch & Dam, 1955) has shown that supplements of linoleic acid substantially improve the growth of rats on diets containing hydrogenated fats.

It is evident from their respective fatty-acid compositions that palm oil contains very little of the short-chain fatty acids, as compared with butterfat. Bhalerao, Venkatappiah & Anantakrishnan (1947) have shown with rats that short-chain fatty acids are more readily absorbed than long-chain ones. Mattil (1946) considered that the main factor limiting the digestibility of fats is the amount of saturated acids present, and that the degree of limitation increases with chain length. It is apparent from the literature that though the influence of certain factors on the digestibility of various fats has been extensively studied the possibility of differences in utilization of digested fats as sources of energy has received very scant attention.

* Paper no. 1: *Brit. J. Nutr.* (1958), **12**, 469.

The investigation described here has been designed to study, by means of digestibility trials and nitrogen balances, the utilization of different fats by very young calves. The diets used were whole milk, separated milk, whole milk supplemented with additional butterfat, separated milk supplemented with unhydrogenated palm oil and separated milk supplemented with a mixture of unhydrogenated palm and palm-kernel oils. The results show that the incorporation of unhydrogenated palm oil in a separated-milk diet for calves brought about a marked improvement in nitrogen retention, in marked contrast to the poor nitrogen-sparing effect of an hydrogenated palm oil (Raven & Robinson, 1958). They also show that partial replacement of unhydrogenated palm oil by unhydrogenated palm-kernel oil, as a means of introducing short-chain fatty acids, did not effect any appreciable improvement in either the digestibility or utilization of the fat. It was also found that the addition of butterfat, as an energy supplement, to a whole-milk diet did not bring about a definite improvement in N retention.

EXPERIMENTAL

Diets

The bulk diets were:

Diet 1 *a*. A spray-dried whole-milk powder.

Diet 5. A spray-dried separated-milk powder.

Diet 6. A reconstituted spray-dried whole-milk powder into which was homogenized about 10% (on a dry-matter basis) of additional butterfat. The operation was carried out in a commercial plant, the fat globule size in the resulting product being less than 2 μ.

Diet 7. A reconstituted spray-dried separated-milk powder into which was homogenized sufficient of an unhydrogenated palm oil to give a fat content of about 30% (on a dry-matter basis). The operation was carried out as for diet 6.

Diet 8. A reconstituted spray-dried separated-milk powder into which was homogenized sufficient of an unhydrogenated palm oil and an unhydrogenated palm-kernel oil, in the ratio of 2 to 1, to give a fat content of about 30% (on a dry-matter basis). The operation was carried out in the same way as for diet 7.

A sufficient quantity of each of diets 6, 7 and 8 to cover a complete preliminary period and a balance test was prepared and stored in milk churns in a refrigerated room at about 3°, the preparation being repeated for the next balance test. Diets 1 *a* and 5 were stored in the dry form.

For diets 1 *a* and 5, after the addition of the vitamin and chlortetracycline supplements (Raven & Robinson, 1958), the equivalents of 283·5 g of dry matter (the amount for one feed) were weighed into enough paper bags to contain a supply of the diet for the whole experiment. With diet 6, the volume of liquid diet required to supply about 312 g of dry matter was given at each feed. With diets 7 and 8, a volume of each diet to provide about 283·5 g of dry matter was given at each feed. The same weights for each feed of the vitamin and chlortetracycline supplements as were added to diets 1 *a* and 5 was added to diets 6, 7 and 8 immediately before feeding.

Before each feed 5 ml of a solution of B vitamins and 5 ml of a solution of minerals were added to all the diets. The composition of the B-vitamin supplement was (per l.):

thiamine hydrochloride 0·224 g, riboflavin 0·770 g, calcium pantothenate 1·456 g, biotin 0·018 g, and choline 59·000 g. The mineral supplement was as previously detailed (Raven & Robinson, 1958).

Experimental animals

Three Ayrshire bull calves were brought in at 3–4 days old and housed in conventional metabolism crates. They were harnessed to facilitate collection of faeces in rubber bags. The metabolism crates were fitted with grid floors and funnels to enable complete collections of urine to be made.

Plan of experiment

Four balance tests, subsequently referred to as periods 1, 2, 3 and 4, were carried out with each animal. Each balance period was preceded by a preliminary feeding period of 3 days, followed by a time lag of 2 days before the collection of faeces and urine, in order to allow for the passage of food through the alimentary tract. With every animal the collection of excreta began on the 5th day and lasted for 6 days. The calves were weighed at the beginning and end of each balance period.

The calves were all given diet 1 *a* for the first period, the diet being reconstituted to give $\frac{1}{2}$ gal of 'milk' at each feed, as detailed by Raven & Robinson (1958), and the B-vitamin and mineral supplements added; feeding was twice daily at 9 a.m. and 5 p.m.

On completion of period 1, diets 6, 7 and 8 were allocated at random, one to each calf. Slightly more than the day's requirement of each diet was withdrawn from the churns of liquid diets each morning. The exact volumes of each diet for the morning feed were then measured into buckets, warmed, and after addition of the vitamin, mineral and chlortetracycline supplements, were immediately given to the calves. This procedure was repeated for the evening feed. One-twentieth of each day's feed was retained to form a bulk sample for analysis and stored in a refrigerator, formalin (0·1 %) being added as preservative.

For period 3, diets 6, 7 and 8 were interchanged at random and the balance tests carried out as for period 2.

During period 4 all the calves received diet 5, which was reconstituted and offered in the same way as diet 1 *a*.

All the animals were maintained in good condition, and food was never refused or scouring observed.

Collection and analysis of samples

The daily collections of faeces and urine were made and treated as previously described (Raven & Robinson, 1958), with the exception that composite samples of wet faeces were not retained.

The diets, the composite samples of dry faeces and the composite samples of urine were analysed as previously described (Raven & Robinson, 1958). Confirmatory determinations of magnesium in some samples of urine were done by the pyrophosphate method (Hawk, Oser & Summerson, 1947).

The saponification values and the iodine values (Wijs's method) of the fats were determined by the procedures of Elsdon (1926).

Table 1. *Chemical composition of the diets on a dry-matter basis*

Diet no.	Calf	Period	Organic matter (%)	Crude protein (%)	Ether-extractable material (%)	N-free extractives (%)	Ash (%)	Ca (%)	P (%)	Mg (%)
1 *a*	1D	1								
	2D	1	94·0	27·6	27·3	39·1	6·02	0·941	0·728	0·106
	3D	1								
5	1D	4								
	2D	4	91·8	38·6	1·46	51·7	8·24	1·250	0·951	0·131
	3D	4								
6	2D	2	94·2	25·0	31·7	37·5	5·78	0·901	0·678	0·091
	1D	3	94·3	24·6	38·1	31·7	5·69	0·870	0·661	0·082
7	1D	2	94·1	26·9	28·2	39·0	5·88	0·957	0·693	0·101
	3D	3	93·8	27·0	32·0	34·8	6·19	0·955	0·723	0·096
8	3D	2	94·1	26·6	27·8	39·7	5·92	0·946	0·697	0·099
	2D	3	93·8	28·2	31·1	34·5	6·19	0·958	0·727	0·104

RESULTS

Chemical composition of the diets

The variations in chemical composition between the diets given in period 2 and their counterparts given in period 3 (Table 1) were due to the bulk liquid diets being prepared in separate batches, immediately before use. The differences in the contents of ether-extractable material in these diets arose owing to the difficulty of preparing rather small quantities of homogenized milk in a large industrial homogenizing plant. These variations were of only minor importance except with diet 6, where in period 2 the addition of butterfat fell appreciably short of the intended 10%.

It should be noted that the percentages of crude protein and N-free extractives in diet 5 were very much higher than in the other diets, owing to its much lower content of ether-extractable material.

Table 2. *Characteristics of the dietary fats*

Type of fat	Melting point (°C)	Saponification value	Iodine value
Butterfat from whole milk in diets 1 *a* and 6	31·3	229·5	38·0
Butterfat as addition in diet 6	33·2	228·2	36·4
Unhydrogenated palm oil in diets 7 and 8	39·2	196·6	51·3
Unhydrogenated palm-kernel oil in diet 8	28·0	245·8	16·4

Table 2 shows that the butterfat added to the whole milk of diet 1 *a*, in order to produce diet 6, had very similar characteristics to the butterfat contained in the dried whole milk. The characteristics of the fats agreed well with those quoted by Elsdon (1926) for butterfat, palm oil and palm-kernel oil.

Digestibility coefficients

The digestibility of the crude protein (Table 3) of all the diets was high, there being no marked differences between diets. The ether-extractable material in the butterfat diets, 1 *a* and 6, was appreciably better digested than in the vegetable-fat diets, 7 and 8.

Calf 3D was lighter than the others receiving the same diet and tended to give relatively lower digestibility coefficients for the organic matter, crude protein and ether-extractable material, but not for the N-free extractives throughout all four periods.

Table 4 shows the extent to which undigested fat had been hydrolysed. The figures for 'total fatty acids' in the faeces represent both the free fatty acids and those present as soaps. The faecal excretion of unsaponifiable material and neutral fat (which is represented by the difference between the ether-extractable material and the total fatty acids) was small, and appears to have been of the same order with all diets, including diet 5 which was virtually fat-free. These results are in good agreement with our earlier ones (Raven & Robinson, 1958). It is also evident, as observed previously with hydrogenated palm oil (Raven & Robinson, 1958), that the undigested vegetable fats of diets 7 and 8 were substantially hydrolysed in the alimentary tract.

This hydrolysis is reflected in the very high proportion of total fatty acids in the ether-extractable material of the faeces resulting from these diets. When the daily excretion of ether-extractable material was low, the fraction comprised of the neutral fat and unsaponifiable material was the dominant fraction of the lipid material.

For reasons previously discussed (Raven & Robinson, 1958) the value for N-free extractives has been used to express the digestibility of the carbohydrate fraction. The digestibility of this fraction was extremely high for all the diets.

Table 3. *Digestibility coefficients of the proximate constituents of the diets*

Diet no.	Calf	Period	Mean live weight of calf* (lb)	Organic matter	Crude protein	Ether-extractable material	N-free extractives
1*a*	1D	1	83	98·4	95·8	99·1	99·4
	2D	1	81	97·3	93·9	99·2	98·5
	3D	1	69	96·6	91·2	98·5	98·9
5	1D	4	111	96·7	95·6	79·5	97·7
	2D	4	109	95·9	93·2	80·0	97·8
	3D	4	97	95·7	93·3	70·1	98·1
6	2D	2	92	98·1	95·6	99·3	99·0
	1D	3	103	98·4	96·2	99·5	98·1
7	1D	2	93	97·0	95·9	94·2	99·9
	3D	3	89	93·1	92·1	88·1	99·5
8	3D	2	80	94·5	88·8	91·4	100·0
	2D	3	100	96·9	94·4	96·3	99·2

* Mean of initial and final weight for each period.

Table 4. *Daily excretion and composition of ether-extractable material in the faeces*

			Ether-extractable material		
				Total fatty-acid content	
Diet no.	Calf	Period	Weight (*a*) (g)	(g)	As percentage of (*a*)
1*a*	1D	1	1·34	0·22	16·4
	2D	1	1·26	0·70	55·6
	3D	1	2·40	1·37	57·1
5	1D	4	1·70	0·55	32·4
	2D	4	1·65	0·47	28·5
	3D	4	2·47	0·82	33·2
6	2D	2	1·47	0·52	35·4
	1D	3	1·25	0·40	32·0
6	1D	2	10·04	8·26	82·3
	3D	3	21·64	19·75	91·3
8	3D	2	14·73	13·53	91·9
	2D	3	6·43	5·30	82·4

Energy digestion

The values for energy intake, and energy digested, per day (Table 5) were calculated by using the mean calorific values for crude protein, ether-extractable material and N-free extractives given by Maynard (1947). In an earlier investigation (Raven & Robinson, 1958), this method gave results in close agreement with those determined in a bomb calorimeter. We therefore considered it justifiable to dispense with the time-consuming bomb-calorimeter determinations.

The very low content of fat in diet 5 (the separated-milk diet) was reflected in the much lower energy values for this diet, as compared with the others. The inclusion of vegetable fats in diets 7 and 8 raised their energy values, both in respect of energy intake and energy digested, to those of diet 1 (the whole-milk diet). The inclusion of additional butterfat in diet 6 and the giving of extra dry matter appreciably increased the intake of energy, and the amount of energy digested, on this diet.

The values for non-protein energy digested show the amounts of energy from this source which each diet supplied. The deficiency of diet 5 in this respect is apparent.

Nitrogen retention

With the exception of diet 5, the daily intake of N on all the diets was similar (Table 5). Although the digestion of N was, in general, uniformly high, marked differences in retention (expressed as a percentage of the N intake) occurred between diets. The N retentions obtained with diet 1 *a* were appreciably higher than the mean retention of 55% previously reported (Raven & Robinson, 1958) for calves receiving a whole-milk diet. It is possible that the outstandingly high retention of N by calf 3D on diet 1 *a* was related to its relatively low weight compared with the weights of calves 1D and 2D when they received this diet. Although the daily intake of N was much greater on diet 5 than on any of the other diets, its retention, in g/day, was markedly less than that on any of the other diets. The additional energy, as butterfat, in diet 6 did not bring about a consistent improvement in the retention of N by calves 1D and 2D, as compared with the retention on diet 1 *a*. The daily retention of N on diets 7 and 8, though considerably better than that on diet 5, was not as high as that on diet 1 *a*.

Calcium, phosporus and magnesium metabolism

The Ca and P of the diets were entirely supplied by the milk constituents but from 9 to 13% of the Mg intake came from the mineral supplement. The high mineral content of separated milk was reflected in the greater intake of Ca, P and Mg by the calves on this diet (diet 5), as compared with those on the other diets (Table 6).

The general pattern of absorption and excretion of Ca and P was similar to that found by Raven & Robinson (1958). Thus, excretion of Ca was mainly in the faeces, urinary excretion being always very low. With P, on the other hand, excretion was mainly in the urine, faecal excretion being very small in comparison. Although the total amount of Mg excreted on each diet was in general fairly consistent, the pattern of excretion showed considerable variation. Thus, a high faecal excretion was usually accompanied by a low urinary excretion and vice versa. Smith (1957) reported retentions of Mg by calves of the same age as ours, on a whole-milk diet, that were similar to those with diet 1 *a*. He also found considerable variation in the pattern of excretion of Mg between different calves.

DISCUSSION

Energy absorption and nitrogen retention

The additional intake of dry matter, in the form of butterfat, on diet 6 did not produce any digestive upsets, and the very large amount of fat in this diet was extremely well

Table 5. *Energy digestion and nitrogen retention*

Diet no.	Calf	Period	Total energy intake (calculated)* (kcal/day)	Total energy digested (calculated)† (kcal/day)	Non-protein energy digested (calculated)‡ (kcal/day)	Nitrogen			
						Intake (g/day)	Apparent digestibility (%)	Retention	
								%	g/day
1*a*	1D	1	3259	3204	2358	25·0	95·8	61·6	15·4
	2D	1	3259	3180	2350	25·0	93·9	59·6	14·9
	3D	1	3259	3149	2344	25·0	91·2	71·6	17·9
5	1D	4	2531	2432	1251	35·0	95·6	30·6	10·7
	2D	4	2531	2404	1252	35·0	93·2	28·2	9·87
	3D	4	2531	2401	1248	35·0	93·3	28·1	9·82
6	2D	2	3963	3897	2997	26·6	95·6	63·5	16·9
	1D	3	3815	3755	2943	23·9	96·2	60·3	14·4
7	1D	2	3579	3446	2545	26·6	95·9	57·9	15·4
	3D	3	3393	3117	2320	24·5	92·1	52·2	12·8
8	3D	2	3534	3293	2475	26·1	88·8	54·4	14·2
	2D	3	3325	3209	2369	25·2	94·4	48·8	12·3

* Calculated from: (crude protein (g) × 5·65) + (ether-extractable material (g) × 9·40) + (N-free extractives (g) × 4·15).

† Calculated from: (digestible crude protein (g) × 5·65) + (digestible ether-extractable material (g) × 9·40) + (digestible N-free extractives (g) × 4·15).

‡ Calculated from: (digestible ether-extractable material (g) × 9·40) + (digestible N-free extractives (g) × 4·15).

Table 6. *Metabolism of calcium, phosphorus and magnesium*

Diet no.	Calf	Period	Calcium: Intake (g/day)	Calcium: Apparent absorption* (%)	Calcium: Retention %†	Calcium: Retention g/day	Phosphorus: Intake (g/day)	Phosphorus: Apparent absorption* (%)	Phosphorus: Retention %†	Phosphorus: Retention g/day	Magnesium: Intake (g/day)	Magnesium: Apparent absorption* (%)	Magnesium: Retention %†	Magnesium: Retention g/day
1*a*	1D	1	5·34	98·3	97·6	5·21	4·13	98·2	76·5	3·16	0·670	85·1	58·1	0·389
	2D	1	5·34	97·8	97·2	5·19	4·13	98·2	76·0	3·14	0·670	79·9	53·3	0·357
	3D	1	5·34	97·7	97·2	5·19	4·13	98·2	82·3	3·40	0·670	96·0	51·6	0·346
5	1D	4	7·11	71·5	71·5	5·08	5·39	96·0	43·2	2·33	0·812	39·2	26·2	0·213
	2D	4	7·11	52·0	51·9	3·69	5·39	85·4	34·0	1·83	0·812	24·0	17·0	0·138
	3D	4	7·11	71·6	71·3	5·07	5·39	94·6	42·9	2·31	0·812	28·4	17·1	0·139
6	2D	2	6·00	96·9	96·7	5·80	4·52	97·9	75·9	3·43	0·679	78·0	47·1	0·320
	1D	3	5·28	96·1	95·9	5·06	4·01	98·0	73·8	2·96	0·571	73·4	44·1	0·252
7	1D	2	5·91	89·9	89·7	5·30	4·28	96·9	69·2	2·96	0·698	78·1	46·3	0·323
	3D	3	5·42	69·1	69·0	3·74	4·11	95·9	59·4	2·44	0·614	61·5	28·0	0·172
8	3D	2	5·80	83·8	83·3	4·83	4·28	96·7	62·9	2·69	0·677	77·2	44·0	0·298
	2D	3	5·35	89·5	89·5	4·78	4·06	96·5	64·0	2·60	0·652	61·2	40·5	0·264

* Apparent absorption (intake – faecal excretion) expressed as a percentage of the intake.
† Retention (intake – faecal and urinary excretion) expressed as a percentage of the intake.

digested. Although the result was a much higher yield of digested energy with this diet as compared with the whole-milk diet (1*a*), it is evident that the additional energy did not bring about any definite increase in daily N retention.

Blaxter & Wood (1952) and Blaxter (1952) have reported much greater daily retentions of N by calves similar to ours but given larger quantities of whole milk. Thus, in our experiment, it seems unlikely that the physiological limit of N retention had been reached. It would appear, therefore, that nutritional factors other than the level of energy in the diet may have exerted a limiting effect.

The very low fat content of diet 5 (the separated-milk diet) was reflected in the low level of digested energy it supplied, as compared with diet 1*a*, the level of non-protein energy being only slightly more than half that of the latter. This deficiency in non-protein energy was probably the main cause of the difference in retention of N on these two diets, presumably because a substantial proportion of the protein of diet 5 had to be deaminated and utilized as a source of energy. This explanation is borne out by the fact that only about 10 g N/day were retained by each calf on diet 5, compared with about 16 g on diet 1*a*. Thus, the butterfat in diet 1*a* improved the percentage retention of N as compared with that on diet 5 and also substantially increased the amount of N retained. This increase occurred in spite of the lower intake of protein resulting from the presence of fat.

We have shown (Raven & Robinson, 1958) that although an hydrogenated palm oil was reasonably well digested by very young calves, the utilization of the energy provided by this hydrogenated oil was very low compared with that of butterfat, as judged by their respective protein-sparing effects. In the investigation reported here diet 7 contained an unhydrogenated palm oil and the retention of N, although not as good as that on diet 1*a*, was nevertheless much better than that brought about by the hydrogenated palm oil. We suggested (Raven & Robinson, 1958) that the poor protein-sparing effect of the hydrogenated palm oil could be explained, at least partly, by its lack of unsaturated fatty acids. This explanation is supported by the improvement obtained with an unhydrogenated palm oil. Aaes-Jørgensen & Dam (1954) showed with rats that although supplementation of hydrogenated arachis oil with linoleic acid brought about a significant improvement, the increase in live weight was not as great as with unhydrogenated arachis oil. Aaes-Jørgensen (1954) has pointed out that the poorer results obtained with hydrogenated oils, as the sole source of dietary fat, may not be related solely to a deficiency of essential fatty acids, and suggested that biologically inert isomers produced during hydrogenation may have harmful effects.

Different methods of hydrogenation may bring about products of widely differing nutritional value, due to such factors as the catalyst, temperature and time of hydrogenation. Quite apart from the effect of these on the possible production of isomers, considerable differences have been found in the rate at which different unsaturated fatty acids are hydrogenated. Bailey & Fischer (1946) found that linoleic and linolenic acids were hydrogenated twenty and forty times as fast, respectively, as oleic acid. It is evident that the blending of unhydrogenated with fully hydrogenated fats will produce products, styled commercially as hydrogenated, which will be very different from originally similar unhydrogenated fats that had undergone mild hydrogenation. The two products, nevertheless, may exhibit the same degree of unsaturation, as indicated by their iodine values. These differences, particularly when they affect the content of essential fatty acids, are of paramount importance, since the requirement for essential fatty acids is increased when saturated fatty acids are given along with a diet deficient in essential fatty acids (Deuel & Reiser, 1955).

An outstanding difference in composition between butterfat and unhydrogenated palm oil is the relatively small amount of short-chain fatty acids in the latter. On the other hand, palm-kernel oil is a good source of these acids, with the exception of butyric acid (Hilditch, 1940). Diet 8, which contained a 2:1 mixture of unhydrogenated palm oil and unhydrogenated palm-kernel oil, did not bring about any improvement in N retention over that on diet 7, which contained only palm oil. Each of the diets was inferior to diet 1 *a* in both digestibility of fat and retention of N. The influence of butyric acid on the digestibility of hydrogenated lard has been studied by Calloway & Kurtz (1956). They stated that butyration of an hydrogenated lard, to the extent of one fatty-acid equivalent, markedly improved its digestibility for rats, but that no improvement resulted from the simple substitution of part of the lard in the diet by tributyrin.

Mineral metabolism

As in our earlier investigation (Raven & Robinson, 1958), the percentage retentions of Ca, P and Mg were related to that of N. The slightly greater N retention on diet 1 *a*, compared with that on the whole-milk diet of the earlier investigation, was accompanied by a slightly better and more uniform retention of Ca, P and Mg.

Since the two lots of diet 6 were prepared at different times, the Ca intakes of calves 1 D and 2 D on this diet were slightly different (5·28 and 6·00 g/day, respectively). It may be of significance that the Ca taken additionally by calf 2 D was well retained, with a concomitant small increase in N retention. A similar tendency was also seen with P. Blaxter & Wood (1952) gave increasing levels of whole milk, up to 6·6 l./day, and obtained increasing daily retentions of N, Ca and P up to maxima of 25·07, 9·08 and 5·29 g, respectively, at the highest level of food intake, which suggests that in our trials lack of Ca and P may have been factors limiting the retention of N on diet 6.

With diet 5, the percentage retentions of Ca, P and Mg were very much lower than with diets 1 *a* and 6. However, the daily retentions of Ca by calves 1 D and 3 D on diet 5 were as great as on diet 1 *a*, presumably owing to the much greater intake of Ca. The similar increase in P and Mg intake did not, however, have a similar effect.

The retention of N on diets 7 and 8 was reasonably high and might have been expected to be accompanied by good mineral retention. It is evident, however, that the apparent absorption of Ca and Mg was adversely affected by the relatively high level of unabsorbed fatty acids in the alimentary tracts of the calves receiving these diets. A similar decrease in absorption of Ca and Mg was found with hydrogenated palm oil (Raven & Robinson, 1958), and was presumably due to the excretion of fatty acids in the form of Ca and Mg soaps. The excretion of fatty acids was greatest with calf 3 D when receiving diet 7 and markedly reduced the absorption of Ca and Mg. The retention of P on diets 7 and 8 appears to have been largely influenced by the degree of Ca retention.

SUMMARY

1. Twelve digestibility trials and tests of nitrogen and mineral balance were done with three calves. The nutritive values of an unhydrogenated palm oil and of an unhydrogenated palm-kernel oil as additions to a separated-milk diet, and of butterfat as an addition to a whole-milk diet, were studied. The balance tests began when the calves were about 1 week old.

2. Although the digestibility of the organic matter in a separated-milk diet was very high (96%), the daily retention of N with this diet was much less than with a whole-milk diet. An energy supplement, in the form of butterfat, to the whole-milk diet did not markedly affect the retention of N.

3. The mean digestibility of the unhydrogenated palm oil was 91% compared with 99% for butterfat. Even when the amount of digestible energy supplied by the palm-oil diet was the same as that supplied by the whole-milk diet, the vegetable oil had a somewhat smaller protein-sparing effect, as assessed by the effect on N retention. The unhydrogenated palm oil had a protein-sparing effect much greater than that obtained with an hydrogenated palm oil in an earlier investigation.

4. Substitution of one-third of the unhydrogenated palm-oil supplement by an unhydrogenated palm-kernel oil slightly raised the mean digestibility of the oil, but did not bring about any improvement in N retention over that with the palm oil alone.

5. The retentions of calcium, phosphorus and magnesium were related to the retention of N, but were also influenced by the degree of fat digestibility. When the excretion of fat was relatively high, as with the vegetable-fat diets, undigested fat was largely excreted in the hydrolysed form. Faecal excretion of Ca and Mg was also increased, which suggests that lipid excretion was mainly in the form of soaps.

We wish to thank Professor R. G. Baskett for his interest and advice, and members of the staff of the Chemical Research Division, Ministry of Agriculture (N.I.) for technical assistance.

REFERENCES

Aaes-Jørgensen, E. (1954). *The Role of Fat in the Diet of Rats*. 6. *Influence of Various Fats in Ordinary Refined State and after Hydrogenation or Polymerization*. Copenhagen: Store Nordiske Videnskabsboghandel.

Aaes-Jørgensen, E. & Dam, H. (1954). *Brit. J. Nutr.* **8**, 296.

Aaes-Jørgensen, E., Engel, P. F., Funch, J. P. & Dam, H. (1955). *Brit. J. Nutr.* **9**, 42.

Bailey, A. E. & Fischer, G. S. (1946). *Oil & Soap*, **23**, 14.

Bhalerao, V. R., Venkatappiah, D. & Anantakrishnan, C. P. (1947). *Indian J. vet. Sci.* **17**, 221.

Blaxter, K. L. (1952). *Brit. J. Nutr.* **6**, 12.

Blaxter, K. L. & Wood, W. A. (1952). *Brit. J. Nutr.* **6**, 1.

Calloway, D. H. & Kurtz, G. W. (1956). *Food Res.* **21**, 621.

Deuel, H. J. Jr. (1948). *Cotton Seed and Cotton Seed Products*. New York: Interscience.

Deuel, H. J. Jr. & Reiser, R. (1955). *Vitam. & Horm.* **13**, 29.

Elsdon, G. D. (1926). *The Chemistry and Examination of Edible Oils and Fats, their Substitutes and Adulterants*. London: Ernest Benn Ltd.

Hawk, P. B., Oser, B. L. & Summerson, W. H. (1947). *Practical Physiological Chemistry*, 12th ed. London: J. and A. Churchill Ltd.

Hilditch, T. P. (1940). *The Chemical Constitution of Natural Fats*. London: Chapman and Hall Ltd.
Lambert, M. R., Jacobson, N. L., Allen, R. S. & Zaletel, J. H. (1954). *J. Nutr.* **52**, 259.
Mattil, K. F. (1946). *Oil & Soap*, **23**, 344.
Maynard, L. A. (1947). *Animal Nutrition*, 2nd ed. New York and London: McGraw-Hill Book Co. Inc.
Raven, A. M. & Robinson, K. L. (1958). *Brit. J. Nutr.* **12**, 469.
Smith, R. H. (1957). *Biochem. J.* **67**, 472.

Diet in pregnancy

2.* Assessment of the nutritive value of diets, especially in relation to differences between social classes

BY A. M. THOMSON

Obstetric Medicine Research Unit (Medical Research Council), University of Aberdeen

(*Received* 17 *September* 1958)

The first paper in this series (Thomson, 1958) described and discussed the methods used in a dietary survey of 489 Aberdeen women pregnant for the first time. Three social classes were distinguished according to the occupations of the husbands, as follows: class A, 'white-collar'; class B, skilled manual; class C, semi-skilled and unskilled. These classes correspond, respectively, to the Registrar-General's social classes I and II, III and IV and V, modified so that non-manual workers in Class III are included within classes I and II. Direct comparison of nutrient intake levels with the summary of allowances recommended for late pregnancy by the British Medical Association: Committee on Nutrition (1950) showed that many diets in all classes were substandard in one or more respects, the proportion rising as social status decreased.

A comparison of this kind is superficial and an inference that many diets were inadequate to support normal pregnancy may not be justified, even if the standards adopted are acceptable. A low calorie intake must be associated with a low intake of protein or fat or carbohydrate, or of any combination of these, and the intakes of many other nutrients are likely to be low also. At least part of the social gradient in the average nutritive value of diets must therefore be simply a reflexion of the social gradient in calorie intakes. It in turn may be determined in part by the well-known fact that average body size decreases with diminishing social status. Finally, since the requirement for some nutrients depends on energy metabolism, the adequacy of the intake of these depends to some extent upon the calorie value of the diet.

Two main problems will be considered in this paper: first, the extent to which intakes of calories and of the various nutrients are interdependent; and, second, the adequacy of the Aberdeen diets when variations of calorie intake are taken into account.

* Paper no. 1: *Brit. J. Nutr.* (1958), **12**, 446.