Studies of the nutrition of the young calf

3.* A comparison of unhydrogenated palm-kernel oil, hydrogenated palm-kernel oil, and butterfat, as constituents of a milk diet

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It has been found in earlier investigations (Raven & Robinson, 1958*a*, 1959) that an hydrogenated palm oil had a much lower protein-sparing effect than an unhydrogenated palm oil when included in a separated-milk diet for calves. This effect occurred even though the levels of energy digested on the diets containing these two types of palm oil were very similar, and was presumably due to differences in metabolism. It was also found that substitution of one-third of the unhydrogenated palm oil by an unhydrogenated palm-kernel oil, so as to provide a plentiful supply of short-chain fatty acids, did not bring about any improvement. In fact the protein-sparing effect of the mixed oils was, if anything, slightly lower than that of the palm oil alone.

This investigation was designed to study, by means of digestibility trials and nitrogen balances, whether the differences found between an hydrogenated and an unhydrogenated palm oil also exist between these two forms of palm-kernel oil. It was also designed to show whether the nutritive value of unhydrogenated palm-kernel oil was inferior to that of unhydrogenated palm oil in a diet of separated milk with added vegetable fat. The comparisons were between whole milk, separated milk, separated milk supplemented with an unhydrogenated palm-kernel oil, and separated milk supplemented with an hydrogenated palm-kernel oil. The results of this investigation have shown that the digestibilities of the two types of vegetable fat were appreciably lower than that of butterfat. The protein-sparing effect of the unhydrogenated palm-kernel oil was slightly lower than that of an unhydrogenated palm oil previously investigated (Raven & Robinson, 1959), but better than that of the two hydrogenated oils. It has also been found that throughout the complete series of trials the retentions of calcium, phosphorus and magnesium have each been closely related to the retentions of N.

EXPERIMENTAL

Diets

The diets were:

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

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

Diet 15. A spray-dried milk powder containing an hydrogenated palm-kernel oil

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in place of butterfat. It was prepared by homogenizing sufficient of the oil with liquid separated milk to produce a 'milk' containing about 28% (on a dry-matter basis) of the oil. The operation was carried out in a commercial plant which ensured that the fat-globule size in the resulting product was less than 2μ. The 'milk' was then spray-dried.

Diet 16. A spray-dried milk powder containing about 28% (on a dry-matter basis) of an unhydrogenated palm-kernel oil. It was prepared in the same way as diet 15.

Supplements of vitamins A and D_3, vitamin E and chlortetracycline were added to the diets as described previously (Raven & Robinson, 1958*a*).

Dry-matter determinations were made on all the diets, and the equivalents of 283·5 g dry matter (the amount for one feed) were weighed into enough paper bags to contain a supply of the diets for the whole experiment.

Experimental animals

Four Ayrshire bull calves were brought in at 3–4 days old and housed in metabolism crates. They were harnessed so that the faeces were collected 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

Three balance tests, subsequently referred to as periods 1–3, were carried out with three of the calves, but only two (periods 1 and 2) with the remaining calf. Each balance 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. The collections of excreta were begun on the 5th day and lasted for 6 days. The calves were weighed at the beginning and end of each balance period.

It was intended that, for period 1, calves 1E and 2E should be given diet 15 (the diet with hydrogenated palm-kernel oil) and calves 3E and 4E diet 16 (the diet with unhydrogenated palm-kernel oil). Calf 2E, however, refused to take diet 15 and consequently was changed on to diet 5*a*, thus completing only two balances. This calf, presumably on account of its small size, did not consume the intended allowance of food, which was, therefore, reduced to an amount equivalent to 240·1 g dry matter at each feed during this first balance period. For period 2 the diets given in period 1 were interchanged, and for the third period, calves 1E, 3E and 4E all received diet 1*c*.

Immediately before feeding, each diet was reconstituted with 1 l. warm water to give 0·5 gal of 'milk' of dry-matter content 12·4%. A solution of a mineral mixture was prepared according to the formula of Blaxter & Wood (1952), and 5 ml were added to each feed, together with 5 ml of a solution of B vitamins, prepared in the manner previously described (Raven & Robinson, 1959). The calves were fed twice daily at 9 a.m. and 5 p.m.

All the animals remained in good condition, and in no instance was any food refused or scouring observed during the balance periods.

Collection and analysis of samples

Faeces and urine were collected daily and treated as previously described (Raven & Robinson, 1958*a*), 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 before (Raven & Robinson, 1958*a*).

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

RESULTS

Chemical composition of the diets

It will be noted from Table 1 that diets 1*c*, 15 and 16 were very similar in proximate composition. With diet 5*a*, however, the very much lower content of ether-extractable material resulted in the percentages of the remaining constituents being proportionately increased.

Certain characteristics of the fats present in diets 1*c*, 15 and 16 are given in Table 2. They show good agreement with figures quoted by 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*c*	1E 3E 4E	3 3 3	94·0	26·8	27·7	39·5	6·00	0·937	0·838	0·110
5*a*	2E 4E	1 2	91·7	38·4	1·30	52·0	8·34	1·28	1·15	0·172
15	1E 3E	1 2	94·1	26·7	27·7	39·7	5·90	0·941	0·851	0·103
16	1E 2E 3E 4E	2 2 1 1	94·1	25·9	28·6	39·6	5·90	0·921	0·831	0·107

Digestibility coefficients

The digestibility of the crude protein in all the diets (Table 3) was fairly good, except with calf 1E on diet 15. The digestibility of the ether-extractable material was also lower with this calf. Since these lower digestibility coefficients were not obtained with diet 16, when the weights of all the calves were similar, they may have been connected with the lower live weight of calf 1E in the instance concerned. A similar association was observed in a previous investigation (Raven & Robinson, 1959).

The coefficients for the ether-extractable material show that the vegetable fats were of somewhat lower digestibility than the butterfat. These lower digestibility coefficients appear to have been accompanied by a lowering of the digestibility of the milk protein.

This tendency was also evident in our previous trials with high-fat diets (Raven & Robinson, 1958*a*, 1959). Johnson, Dolge, Rousseau, Teichman, Eaton, Beall & Moore (1956) found that the inclusion of tallow in a starter ration for calves resulted in a slight lowering of digestibility of crude protein.

Table 2. *Characteristics of the dietary fats*

Type of fat	Melting point (°C)	Saponification value	Iodine value
Butterfat in diet 1*c*	30·5	229·1	41·3
Hydrogenated palm-kernel oil in diet 15	38·0	244·7	7·4
Unhydrogenated palm-kernel oil in diet 16	27·7	246·8	17·2

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*c*	1E	3	89	94·9	90·9	98·7	94·7
	3E	3	100	95·6	92·5	95·6	97·3
	4E	3	98	96·6	92·9	97·4	98·3
5*a*	2E	1	66	93·9	91·0	64·2	96·3
	4E	2	89	95·8	93·4	71·0	97·9
15	1E	1	74	87·8	77·1	81·5	98·7
	3E	2	92	95·3	91·9	93·9	98·0
16	1E	2	81	91·8	85·9	88·2	97·6
	2E	2	76	90·6	86·2	84·8	97·0
	3E	1	84	93·0	88·7	89·9	97·6
	4E	1	83	89·6	81·9	85·8	97·2

* Mean of initial and final weight for each period.

Table 4 indicates the extent to which unabsorbed fat was hydrolysed in the alimentary tract. The figures for 'total fatty acids' in the faeces represent both the free fatty acids and those present as soaps. As in previous investigations (Raven & Robinson, 1958*a*, 1959) there was a small and fairly constant excretion of unsaponifiable material and neutral fat (represented by the difference between the values for ether-extractable material and those for total fatty acids). It is also evident that with the vegetable-fat diets the faecal lipids were mainly in the hydrolysed form, and that the proportion of total fatty acids in the lipid fraction increased as the daily excretion of lipid material increased. In the two instances in which this proportion exceeded 100% the error was probably due to the actual mean equivalent weight of the fatty acids being less than the assumed one of 284 (stearic acid) used in calculating the weights of fatty acids excreted.

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

Energy digestion

The values for energy intake and energy digested per day (Table 5) were calculated by using the mean calorific values for the crude protein, ether-extractable material and N-free extractives given by Maynard (1947). For reasons previously discussed (Raven & Robinson, 1959), it was considered justifiable to dispense with bomb-calorimeter determinations.

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

			Ether-extractable material		
				Total fatty-acid content	
Diet no.	Calf	Period	Weight (*a*) (g)	g	As percentage of (*a*)
1 *c*	1 E	3	2·00	0·87	43·7
	3 E	3	6·97	5·51	79·1
	4 E	3	4·07	2·99	73·5
5 *a*	2 E	1	2·24	1·16	51·8
	4 E	2	2·14	1·05	49·1
15	1 E	1	29·01	27·18	93·7
	3 E	2	9·59	8·86	92·4
16	1 E	2	19·24	19·74	102·6
	2 E	2	24·64	26·01	105·6
	3 E	1	16·51	14·28	86·5
	4 E	1	23·00	21·31	92·7

The very low fat content of diet 5 *a* (the separated-milk diet) was reflected in the much lower values for energy intake and energy digested as compared with the respective values with diet 1 *c* (the whole-milk diet). The inclusion of the two types of palm-kernel oil in diets 15 and 16 raised the daily intake of energy on these diets to almost that on diet 1 *c*. The lower digestibility of the former diets, however, resulted in the levels of energy digested on these diets being slightly lower than those on diet 1 *c*.

Nitrogen retention

With the exception of diet 5 *a*, the daily intake of N on all the diets was similar (Table 5). The difference between the intakes of N by calves 2 E and 4 E on this diet arose because calf 2 E, presumably by reason of its low live weight, would only eat during this period an appreciably smaller daily amount of dry matter than did calf 4 E.

The percentage retentions of the N of diet 1 *c* by two of the calves (1 E and 4 E) were similar to those obtained with a whole-milk diet in one previous investigation (Raven & Robinson, 1958 *a*), but not as high as in another (Raven & Robinson, 1959). In the series of trials which we have carried out there was a marked tendency for the heavier calves to retain nitrogen less efficiently and to digest vegetable fat more efficiently than lighter ones. Hence the surprisingly low retention of 40·9% by the third calf (calf 3 E) may be related to this calf's being much heavier than those used in the earlier

Table 5. *Energy digestion and nitrogen retention by the calves*

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 *c*	1 E	3	3263	3117	2336	24·4	90·9	55·7	13·6
	3 E	3	3263	3108	2313	24·4	92·5	40·9	9·98
	4 E	3	3263	3147	2349	24·4	92·9	52·9	12·9
5 *a*	2 E	1	2135	1983	1036	29·5	91·0	22·9	6·75
	4 E	2	2522	2394	1246	34·8	93·4	38·5	13·4
15	1 E	1	3265	2784	2125	24·2	77·1	34·6	8·38
	3 E	2	3265	3086	2301	24·2	91·9	43·4	10·5
16	1 E	2	3287	2963	2249	23·5	85·9	43·0	10·1
	2 E	2	3287	2912	2096	23·5	86·2	48·5	11·4
	3 E	1	3287	3016	2279	23·5	88·7	47·2	11·1
	4 E	1	3287	2894	2214	23·5	81·9	44·7	10·5

* 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 by the calves*

			Calcium				Phosphorus				Magnesium			
				Apparent absorption*	Retention			Apparent absorption*	Retention			Apparent absorption*	Retention	
Diet no.	Calf	Period	Intake (g/day)	(%)	%†	g/day	Intake (g/day)	(%)	%†	g/day	Intake (g/day)	(%)	%†	g/day
1c	1E	3	5·31	94·9	94·5	5·02	4·75	98·7	82·5	3·92	0·693	51·7	50·8	0·352
	3E	3	5·31	70·6	70·2	3·73	4·75	92·6	56·2	2·67	0·693	24·3	22·7	0·157
	4E	3	5·31	85·2	84·6	4·49	4·75	93·6	72·8	3·46	0·693	49·8	45·5	0·315
5a	2E	1	6·17	48·0	47·2	2·91	5·52	93·3	46·0	2·54	0·900	27·6	15·3	0·138
	4E	2	7·28	78·9	78·3	5·70	6·52	97·7	64·6	4·21	1·050	41·3	34·0	0·357
15	1E	1	5·34	44·1	43·6	2·33	4·83	78·8	47·4	2·29	0·657	17·5	8·83	0·058
	3E	2	5·34	69·9	69·5	3·71	4·83	95·6	57·3	2·77	0·657	29·7	28·9	0·190
16	1E	2	5·22	66·3	65·9	3·44	4·71	94·5	60·7	2·86	0·677	31·0	30·3	0·205
	2E	2	5·22	42·2	41·8	2·18	4·71	94·6	50·1	2·36	0·677	20·2	18·9	0·128
	3E	1	5·22	59·0	58·4	3·05	4·71	95·3	59·9	2·82	0·677	36·5	33·5	0·227
	4E	1	5·22	61·2	60·2	3·14	4·71	92·2	60·9	2·87	0·677	40·4	22·2	0·150

* 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.

investigations, but, if so, it is difficult to account for the much better retention made by calf 4E than by calf 3E in the present trials, since these calves were of similar weights during the balance period.

Whereas the percentage retention by calf 2E of the N of diet 5*a* agreed well with values previously obtained with a separated-milk diet (Raven & Robinson, 1959), that by calf 4E on this diet was markedly higher. It should be noted that these two calves differed markedly in live weight and in food intake. It is of interest to examine particularly the results obtained with calves 1E and 3E on diets 15 and 16, as these two calves received both diets. It is evident that the percentages of nitrogen retained by these calves were somewhat greater on diet 16 (unhydrogenated oil) than on diet 15 (hydrogenated oil). However, the retention on diet 16 was appreciably lower than that on diet 1*c*, if the exceptional result obtained with calf 3E on the latter diet is excluded.

Calcium, phosphorus and magnesium metabolism

The Ca and P of the diets were entirely supplied by the milk constituents, but from 7 to 11% of the Mg (Table 6) came from the mineral supplement. The greater intakes of Ca, P and Mg on diet 5*a* were due to the higher mineral content of separated milk compared with that of the high-fat milks.

The paths of excretion of Ca and P were similar to those found in previous investigations (Raven & Robinson, 1958*a*, 1959), Ca being excreted almost entirely in the faeces and P mainly in the urine. As in a previous investigation (Raven & Robinson, 1959), the path of Mg excretion was rather variable, but now most was always excreted in the faeces.

Whereas the retentions of Ca, P and Mg by calves 1E and 4E on diet 1*c* are in good agreement with those previously obtained with a whole-milk diet (Raven & Robinson, 1958*a*, 1959), those by calf 3E were all appreciably lower and thus appear to be related to the lower N retention by this calf. With diet 5*a*, the relatively high N retention by calf 4E as compared with calf 2E was accompanied by markedly better retentions of Ca, P and Mg.

DISCUSSION

It appears that the difference between the digestibility coefficients for the hydrogenated palm-kernel oil, with calves 1E and 3E, was at least partly due to the difference in live weight between these calves. On the other hand, calf 1E had received only colostrum for about 3 days before being given diet 15, whereas calf 3E had already completed a balance period on diet 16 (the diet with unhydrogenated palm-kernel oil). A comparison of the results obtained with diets 15 and 16 for each of these calves indicates a progressive improvement in ability to digest vegetable fats, similar to that previously reported (Raven & Robinson, 1958*a*). This tendency has not been found with butterfat, for which most of the calves used in this and previous investigations (Raven & Robinson, 1958*a*, 1959) showed maximum digestibility at the outset. It is also evident from these investigations that, with milk diets, calves consistently digest butterfat better than either hydrogenated or unhydrogenated palm or palm-kernel oil. Furthermore, the differences in digestibility between the four kinds of vegetable oils studied were, if any, so slight as to be obscured by between-calf differences.

Some of the factors that may influence the digestibility of a fat have been previously discussed (Raven & Robinson, 1959). They include melting-point, proportions of long- and short-chain fatty acids, and the degree of saturation in relation to chain length. It appears to be generally accepted that if the melting-point is below 50°, differences in melting-point have very little influence on digestibility. The vegetable fats studied in the complete series of trials had a range in melting-point of from 27·7 to 39·2°, the butterfat having intermediate values. The results are therefore in agreement with the general conclusion drawn from experiments with other animals. The data of Hilditch (1940) show that palm-kernel oil contains a much higher proportion of short-chain fatty acids than either butterfat or palm oil. However, these differences in fatty-acid composition do not appear to have had any direct effect on digestibility in our series of investigations.

According to typical figures given by Hilditch (1940), unhydrogenated palm-kernel oil possesses a much higher proportion of saturated fatty acids than either butterfat or unhydrogenated palm oil. This feature, however, did not appear to bring about lower digestibility and, furthermore, hydrogenation of both the vegetable fats, which gave increased proportions of saturated acids, also did not lower digestibility.

In a recent investigation Calloway & Kurtz (1956) found seven natural fats to be highly digestible for rats. The hydrogenated forms of these fats, however, differed widely in digestibility, and the authors considered that digestibility was primarily dependent upon the amounts and chain length of the saturated fatty acids, and their arrangement within the glyceride structure. Though the considerable differences in chain length and degree of saturation of the fats studied in our investigations with calves do not appear to have influenced digestibility, it is possible that fundamental differences in glyceride structure may have accounted for the lower digestibility of the vegetable fats as compared with butterfat. Calloway & Kurtz (1956) found that modification of an hydrogenated lard by 'butyration to the extent of one fatty acid equivalent' markedly improved the digestibility of the remaining part of the lard triglycerides, whereas a simple admixture of tributyrin with the hydrogenated lard had no effect. As several of the fats used in their investigations did not contain butyric acid and yet had digestibilities of almost 100%, it would appear that butyric acid may not be fundamentally necessary for very high digestibility. The findings do, however, suggest that glyceride structure is of considerable importance.

Energy absorption and nitrogen retention

The intake of non-protein energy by calf 2E on diet 5*a* was very low, which was probably the main cause of the poor nitrogen retention by this calf, presumably because a substantial proportion of the protein had to be deaminated and utilized as a source of energy. The other calf on this diet (calf 4E) had a higher daily intake of non-protein energy, owing to its larger food intake, which apparently was sufficient, in spite of its greater body-weight, to enable it to retain as much N as the calves on diet 1*c*. The N retention, 38·5%, was, however, very much less than the retentions usually obtained with whole-milk diets. It was, nevertheless, appreciably higher than the retentions of 28–30% previously obtained with a separated-milk diet (Raven & Robinson, 1959); this difference is probably related to the smaller weight of calf 4E compared with the weights of the earlier calves.

The N retentions of 34·6 and 43·4% on diet 15 (hydrogenated palm-kernel oil) were of the same order as the retentions of 33–38% obtained with a diet with hydrogenated palm oil in an earlier investigation (Raven & Robinson, 1958*a*). It is also evident from the results of this and previous investigations (Raven & Robinson, 1958*a*, 1959) that the unhydrogenated forms of these two oils have shown better protein-sparing effects than the corresponding hydrogenated oils. The suggestion that the poorer results obtained with hydrogenated oils are due to lack of essential fatty acids, and possibly to the production, during hydrogenation, of biologically inert isomers, has been previously discussed (Raven & Robinson, 1959). The protein-sparing effect of the unhydrogenated palm-kernel oil used in the present investigation was rather lower than that of the unhydrogenated palm oil previously studied (Raven & Robinson, 1959), a result which supports the earlier finding that an increase in the proportion of short-chain fatty acids, as supplied by palm-kernel oil, does not result in any improvement in protein-sparing quality.

In view of the differences in protein-sparing effect encountered between fats supplying apparently similar levels of energy on absorption, it is of interest to determine the connexion between the level of digestible energy and the efficiency with which absorbed N was retained. The correlation coefficient between the total digested energy and the percentage retention of absorbed N for all the results from comparable treatments obtained in this and earlier investigations (Raven & Robinson, 1958*a*, 1959) was +0·583 (significant at $P = 0{\cdot}01$, $n = 25$). The separated-milk diets were excluded because of their appreciably higher protein content. The correlation between non-protein energy digested and percentage retention of absorbed nitrogen ($r = +0{\cdot}565$) was also significant ($P = 0{\cdot}01$). As milk protein constituted the sole source of protein in all instances and its level of intake was almost constant, it is evident that in spite of the modifying factors already discussed, the level of digestible energy in the diet has had a profound influence on the efficiency of N retention. Sibbald, Berg & Bowland (1956) found that about 69% of the variation in N retention by weanling rats was associated with consumption of digestible energy when the effects of initial weights were removed. Subsequently, Sibbald, Bowland, Robblee & Berg (1957) stated that the percentage of apparent digestible N retained by weanling rats was largely controlled by the ratio of apparent digestible energy to apparent digestible N of the food, and they reported a highly significant correlation coefficient of +0·906. Brisson, Cunningham & Haskell (1957), from experiments with calves, have reported a linear regression of N balance on intake of digestible calories. It should be appreciated, however, that many additional factors influence this general relationship. The complexity of the subject has been discussed in reviews by Allison (1951) and by Munro (1951).

Mineral metabolism

As in previous experiments with a diet of separated milk with added vegetable fats (Raven & Robinson, 1958*a*, 1959), with a meal-mixture–whole-milk diet (Raven & Robinson, 1958*b*) and with a rye-grass–flaked-maize diet (Raven & Robinson, 1958*c*), the retentions of Ca, P and Mg were closely related to the retentions of N. In particular, the percentage retentions of Ca, P and Mg by calf 4E on diet 5*a* were markedly better than those by calf 2E on the same diet and were associated with markedly better N retention. Similarly, the fairly good retention of minerals on diets 15 and 16 was associated with fairly high N retention.

About 99% of the Ca of the body is present in the bones and teeth, whereas N, although present in the bone, is mainly found as a constituent of the organs and soft tissues of the body. However, a significant correlation coefficient of +0·743 ($P = 0{\cdot}001$, $n = 30$) was found between the weights of N and Ca retained from each of the milk-substitute diets in the complete series of investigations. It would appear that any factor bringing about a reduction in N retention also tends to result in a lowering of Ca retention, and hence a reduced rate of bone development. The correlation between N retained and Ca retained was even higher ($r = +0{\cdot}803$) when the effect of variation in fatty-acid excretion was removed. The correlations between the retentions of N and P ($r = +0{\cdot}709$) and between those of N and Mg ($r = +0{\cdot}778$) were also significant ($P = 0{\cdot}001$). When the effect of variation in fatty-acid excretion on Mg retention was removed, the partial correlation between the retentions of N and Mg was +0·784.

It is evident that, as in previous trials with diets containing vegetable fats (Raven & Robinson, 1958*a*, 1959), a low absorption of Ca and Mg was associated with a relatively large faecal excretion of fatty acids. This association was presumably due to the excretion of fatty acids as Ca and Mg soaps. Johnson *et al.* (1956) found an increase in faecal Ca when tallow of about 80% digestibility was included in rations for calves. A statistical examination of the correlation between the daily faecal excretions of fatty acids and Ca with the vegetable-fat diets was complicated by the fact that an increase in fatty-acid excretion was accompanied by a reduction of the total energy digested from the diet. This effect would tend to lower N retention and therefore Ca retention, resulting in a greater excretion of faecal Ca, since urinary excretion was very small. However, for all the vegetable-fat diets studied, the partial correlation between the daily faecal excretions of fatty acids and of Ca (when the effect of N retention was kept constant) was very high ($r = +0{\cdot}837$) and proved significant ($P = 0{\cdot}001$, $n = 10$). Although the same trend was evident with Mg, the correlation coefficient failed to reach significance at $P = 0{\cdot}05$.

It was to be expected that the good correlations between the retentions of N and of Ca, P and Mg would be accompanied by good correlations between the retentions of the mineral elements themselves. It proved to be so, as shown by the significant correlations between Ca and P, between Ca and Mg, and between P and Mg, of +0·679, +0·792 and +0·789 respectively ($P = 0{\cdot}001$, $n = 30$), for all the results obtained in this series of investigations.

Agreement between the true retentions and those calculated by the procedure suggested by Blaxter & Rook (1954) was variable, the calculated retentions averaging about 24% less than those obtained experimentally.

SUMMARY

1. Eleven digestibility trials, and nitrogen and mineral balances, were carried out with four calves, beginning when the calves were 1 week old. The nutritive values of an unhydrogenated palm-kernel oil and an hydrogenated palm-kernel oil, as additions to a separated-milk diet, were studied and compared with the nutritive value of the butterfat in a whole-milk diet.

2. The mean digestibilities of the unhydrogenated palm-kernel oil, the hydrogenated palm-kernel oil and the butterfat were 88, 87 and 97% respectively. The lower digestibility of the vegetable fats was associated with a somewhat lower digestibility of the crude protein.

3. Although the unhydrogenated palm-kernel oil had a rather better protein-sparing effect than the hydrogenated oil, as assessed by N retention, it never achieved the maximum effect found with butterfat in this and two earlier investigations. It was inferior in protein-sparing effect to an unhydrogenated palm oil studied previously.

4. The weights of calcium, phosphorus and magnesium retained were, as in two previous investigations, related to the weights of N retained. The correlation coefficients between N and Ca, P and Mg derived from the combined results of the three investigations were all significant ($P = 0{\cdot}001$, $n = 30$). These combined results also indicated that increased excretion of fatty acids with the vegetable-fat diets was associated with increased faecal excretion of Ca, the correlation being significant at $P = 0{\cdot}001$.

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