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Studies of the nutrition of the young calf

A comparison of starch, lactose, and hydrogenated palm oil, with butterfat, in milk diets

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Calves are generally reared artificially, the normal farm practice being to feed on liquid diets from a bucket until the animal is from 8 to 12 weeks old. Whole milk is usually given for the first few weeks, but as soon as possible less expensive milk substitutes based on separated milk are introduced. The published results of numerous feeding trials show the superiority of whole milk during the first few weeks of the animal's life over any milk-substitute diet so far investigated. This superiority is not subsequently so well marked, as judged by live-weight gains and freedom from digestive upsets, but is nevertheless apparent.

The main difference between whole milk and most milk-substitute diets available to the farmer lies in the replacement of fat by lactose, glucose, sucrose and cereal starches, which suggests that the relatively poorer performance of very young calves on milk-substitute diets is brought about by the lower calorific value of the substitute diets and by the inability of such calves to digest certain carbohydrates.

In most investigations with calves comparing whole milk with milk-substitute diets, the basis of assessment has been that of live-weight gain. Therefore, little information is available as to the nutritional factors involved. The present investigation has been designed to study, by means of digestibility trials and nitrogen balances, the utilization of nutrients by very young calves. The diets used were whole milk, and separated milk supplemented with lactose, lactose and starch, and vegetable fat. The results of the preliminary trials now described indicate that the nutritional superiority of whole milk over milk-substitute diets may be largely due to the nature and quantity of the fat in the diet.

EXPERIMENTAL

Diets

The bulk diets were:

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

Diet 2. A spray-dried milk powder containing hydrogenated palm oil (m.p. 35°) in place of butterfat, so that the protein content of the product was similar to that of an average whole-milk powder. It was prepared by homogenization of the oil with liquid skim milk followed by spray-drying (the fat-globule size was less than 2μ). The operation was carried out in a commercial plant.

Diet 3. A spray-dried milk powder containing lactose in place of butterfat. It was prepared by mixing skim-milk powder with lactose, so that the protein content of the resulting product was similar to that of an average whole-milk powder.

Diet 4. Diet 3 with maize starch (cornflour) added, so that the intake of starch-equivalent would be similar to that on diet 1 if the starch was 100% digestible.

These diets were devised so that the protein intake could be kept constant while the source and quantity of non-protein energy were varied. A vitamin A and D_3 supplement was added to each of the diets to give 2400 i.u. vitamin A and 300 i.u. vitamin D_3/lb. diet, and a vitamin E supplement (Roche vitamin E premix) to give 5 mg DL-α-tocopheryl acetate/lb. diet. Chlortetracycline was added at the rate of 40 mg/lb. diet.

Dry-matter determinations were made on all the diets, and for diets 1, 2 and 3 sufficient paper bags to cover the whole experiment were each filled with the equivalent of 283·5 g dry matter (the amount for one feed). To determine the quantity of diet 4 to be given at each feed, the gross-energy values of diets 1 and 4 were determined by a bomb calorimeter. The quantity of diet 4 necessary to supply an intake of calories at each feed similar to that from diet 1 was calculated and weighed into paper bags.

Experimental animals

The animals were Ayrshire bull calves, brought in at 3–4 days old and housed in conventional metabolism crates. They were harnessed to facilitate collection of faeces in rubber bags. It was intended to collect urine by means of rubber funnels harnessed to the animals, but it was found that the very young calves used in this investigation did not always stand up before passing urine and therefore some losses occurred. Consequently, complete urine collections could only be made in two of the metabolism crates which were fitted with grid floors and lead funnels for collection of urine.

Plan of experiment

Two similar trials were carried out with four calves. In each trial all four diets were tested, one diet being assigned to each calf. The diets were allocated at random. A preliminary feeding period of 5 days was followed, with two exceptions, by two consecutive collection periods of 6 days, periods 1 and 2. With calf 3A, period 2 lasted only 5 days. Calf 2A died at the end of period 1, and for this reason the results for the first 4 days only have been used; the second period on this diet was with calf 4A after it had completed its balances on diet 3.

A time-lag of 2 days was allowed for the passage of food through the alimentary tract before collection of faeces. The calves were weighed at the beginning and end of each trial.

Immediately before each feed, the diets were reconstituted with 2 l. warm water. With diets 1, 2 and 3 this 'milk' had a dry-matter content of 12·4% in both trials, and with diet 4 a dry-matter content of 16·4% in trial 1 and 16·1% in trial 2. A solution of a mineral mixture was prepared according to the formula of Blaxter & Wood (1952), and 5 ml. were added to each feed. The calves were fed twice daily, at 9 a.m. and 5 p.m. With the exception of the calf that died, all the animals were maintained in good condition. In no instance was any food refused or scouring observed.

Collection and analysis of samples

Immediately after feeding, faeces were collected, weighed and samples taken for analysis. One-quarter of the total weight of each collection was used to form a composite wet sample for the whole period, it being preserved by the addition of mercuric chloride. One half was dried at 65° and used to form a composite dry sample for the whole period. The remainder was used for daily duplicate dry-matter and N determinations. Urine was collected daily, measured and one-tenth of the volume bulked and stored at about 5°.

Before chemical analysis the composite samples of dry faeces were milled to pass through a $\frac{1}{32}$ in. sieve. The crude protein (N × 6·25) and ash constituents were determined by the methods specified in the Fertilizers and Feeding Stuffs (Northern Ireland) Regulations (Northern Ireland Parliament, 1955) and the organic matter by subtracting the percentage of ash from 100. As the normal Soxhlet procedure for determining ether extract cannot be applied to diets and faeces of this nature, the determination of ether-extractable material was carried out by the method for dried milk recommended by the Society of Public Analysts, as described by Richmond, Elsdon & Walker (1942). The total fatty acids were determined by taking up the ether-extractable material in 10 ml. ethyl alcohol (96%), heating and titrating hot with 0·1 N-NaOH with phenolphthalein as indicator. The final calculation was made on the assumption that the mean molecular weight of the acids present was 284. The percentage of N-free extractives was obtained by summating the percentages of crude protein, ash and ether-extractable material, and subtracting from 100. Gross-energy values of the diets and faeces were determined by means of a bomb calorimeter. The determination of lactose in the diets was by the method of Lane & Eynon (Richmond *et al.* 1942), after removal of the fat and protein by the zinc acetate–potassium ferrocyanide procedure, as described by Richmond *et al.* (1942). The total reducing sugar in the composite wet faeces was similarly determined, both before and after hydrolysis with N-H_2SO_4. Reducing sugars present in the urine were determined by the method of Lane & Eynon (Richmond *et al.* 1942). Starch in the diets and composite dried faeces was determined by the method of Clegg (1956).

The determinations of calcium, magnesium, and phosphorus in the diets and composite dried faeces, and Ca and Mg in the urine, were made as described by Raven & Robinson (1957). P in the urine was determined by the method of Hanson (1950) after wet digestion of the samples with HNO_3.

RESULTS

Chemical composition of the diets

From the values given in Table 1, it will be noted that because of the addition of cornflour the contents of crude protein and mineral constituents in diet 4 were appreciably lower than those of the other diets. In fact, the animals on diet 4 received the full ration of diet 3, together with the supplement of cornflour. Thus the daily intake of crude protein and minerals on all the diets was approximately the same.

The value for N-free extractives has been used for all calculations. In diets 1, 2 and 3 it was very similar to the lactose figure but in diet 4 it included the starch. The percentages of starch in the dry matter of diet 4 were 28·4 and 26·9 for trials 1 and 2, respectively.

Digestibility coefficients

With one exception, the digestibility of crude protein (Table 2) was high. In the first period of trial 2, calf 2B digested the crude protein of diet 2 relatively poorly. This calf, and calf 3A, also digested relatively poorly the ether-extractable fraction during their first periods, but improved considerably in the second periods, which followed immediately. As previously stated, there was no visible indication of scouring which could have brought about these lowered digestibility coefficients.

The extent to which undigested fat was hydrolysed in the alimentary tract is shown in Table 3. It should be appreciated that 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 diets 3 and 4 which were virtually fat-free. It never exceeded 2·5 g/day, which is in good agreement with the figure for this fraction cited by Blaxter & Wood (1953) for 'normal' faeces. It should be noted that most of the undigested fat in diet 2 was hydrolysed in the alimentary tract, resulting in a very high percentage of total fatty acids in the ether-extractable material of the faeces. As the daily excretion of unsaponifiable material and neutral fat from diet 2 was similar to that from the other diets, its influence on the proportion of total fatty acids in the ether-extractable material has therefore been much less.

For expressing the digestibility coefficients of the carbohydrates, which were very

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

Diet no.	Trial no.	Organic matter (%)	Crude protein (%)	Ether-extractable material (%)	N-free extractives (%)	Gross energy (Cal./g)	Ash (%)	Ca (%)	P (%)	Mg (%)
1	1	93·9	25·6	29·3	39·0	5·73	6·09	0·976	0·755	0·106
	2	93·6	28·4	30·2	35·0	5·97	6·36	1·05	0·788	0·116
2	1	94·2	25·3	26·0	42·9	5·45	5·77	0·880	0·679	0·095
	2	94·2	26·0	25·7	42·5	5·40	5·82	0·890	0·683	0·090
3	1	93·9	26·6	0·70	66·6	4·24	6·10	0·957	0·691	0·093
	2	94·0	26·1	1·25	66·7	4·15	6·00	0·984	0·735	0·083
4	1	95·4	19·5	0·82	75·1	4·14	4·60	0·734	0·540	0·071
	2	95·6	19·6	1·14	74·9	4·09	4·45	0·728	0·561	0·078

Table 2. *Digestibility coefficients of the proximate constituents of the diets*

Diet no.	Trial no.	Calf*	Period	Mean live weight of calf (lb.)†	Organic matter	Crude protein	Ether-extractable material	Starch	N-free extractives
1	1	1A	1	71	96·1	90·0	97·3	—	99·0
		1A	2	75	97·0	92·7	97·9	—	99·1
	2	1B	1	78	92·9	88·6	91·9	—	98·7
		1B	2	83	96·3	90·8	96·8	—	98·6
2	1	3A	1	81	91·3	87·3	86·0	—	96·7
		3A	2	86	94·6	88·9	92·2	—	99·4
	2	2B	1	79	83·7	76·7	76·2	—	92·5
		2B	2	80	92·3	88·2	92·2	—	95·0
3	1	4A	1	81	94·9	93·0	74·1	—	95·8
		4A	2	82	90·3	87·0	42·3	—	92·4
	2	3B	1	80	92·5	82·0	71·7	—	96·9
		3B	2	84	95·0	86·1	78·9	—	98·2
4	1	2A	1	65	78·0	87·9	51·9	52·0	75·8
		4A	2	88	81·3	91·3	57·5	62·0	78·8
	2	4B	1	83	77·4	88·6	69·8	48·2	74·5
		4B	2	88	77·7	86·7	57·0	51·1	75·7

* The calves in trial 1 were identified as 1A, 2A, 3A and 4A, and those in trial 2 as 1B, 2B, 3B and 4B.
† Mean of initial and final weight for each period.

high with diets 1, 2 and 3, the values for N-free extractives were used in preference to those for lactose and starch (Table 2). On summation of the contents of crude protein, ether-extractable material, lactose and ash in the faeces resulting from diets 1, 2 and 3, an amount within the range of 6–24 % of the total faecal dry matter was still unaccounted for. Since this discrepancy was low with diet 1 and high with diet 3 (high-lactose diet), the fraction concerned was presumably some non-reducing material derived from the carbohydrate. Presumably, it is similar to the 'residual carbohydrate' of Blaxter & Wood (1951). It was therefore thought that the use of the values for N-free extractives was the best way of expressing the digestibility of the carbohydrates. It is noteworthy that little or no reducing sugar was found in the faeces resulting from diets 1, 2 and 3, either before or after hydrolysis with N-H_2SO_4. None of the urines contained more than a trace of reducing sugar.

Table 3. *Daily excretion and composition of ether-extractable material in the faeces*

				Ether-extractable material		
					Total fatty-acid content	
Diet no.	Trial no.	Calf	Period	Weight (*a*) (g)	g	As percentage of (*a*)
1	1	1A	1	4·53	2·60	57·4
		1A	2	3·50	1·87	53·4
	2	1B	1	13·82	12·2	88·5
		1B	2	5·44	4·23	77·8
2	1	3A	1	20·65	21·5	104·2
		3A	2	11·43	10·6	92·7
	2	2B	1	34·58	34·1	98·5
		2B	2	11·30	10·6	94·2
3	1	4A	1	1·03	0·40	38·8
		4A	2	2·29	0·91	39·7
	2	3B	1	2·00	0·82	41·0
		3B	2	1·50	0·60	40·0
4	1	2A	1	3·10	1·08	34·8
		4A	2	2·74	1·11	40·5
	2	4B	1	2·64	1·02	38·6
		4B	2	3·76	1·27	33·8

The digestibility coefficients for the starch in diet 4 were calculated from the quantities of starch isolated from the diets and faeces. Thus the coefficients are based on the amount of starch hydrolysed in the alimentary tract and do not take into account any products derived from this hydrolysis which may have appeared in the faeces. This procedure was used because it was not possible to differentiate in the faeces between the breakdown products of lactose and those of starch. The digestibility coefficient of the N-free extractives for diet 4 thus includes starch and its possible breakdown products, as well as the fractions already associated with the other diets; the low coefficients obtained are largely a reflection of the low apparent digestibility of starch.

Energy digestion

The energy provided by the digestible nutrients of diets 1 and 2, which contained fat, was considerably higher than that provided by diet 3, where the non-protein energy was entirely supplied by lactose (Table 4). The slightly lower figure for diet 2, as compared with diet 1, was due to the slightly lower level of fat in the diet and the somewhat lower digestibility of this fraction, particularly in the first periods. Although the additional intake of diet 4 raised the daily calorie intake to that from diet 1, the energy of the nutrients digested was much less because of the poor digestibility of the starch.

The values for 'calculated digestible energy' were obtained from the percentages of digestible crude protein, digestible ether-extractable material and the digestible N-free extractives obtained in these trials, together with the mean calorific values for these fractions given by Maynard (1947), namely 5·65, 9·40 and 4·15 Cal./g, respectively. These calculated figures closely correspond to the actual figures obtained in a bomb calorimeter.

Nitrogen retention

Although the digestion of N tended to be uniformly high on all diets, considerable differences in retention (expressed as a percentage of the N intake) occurred between diets (Table 4). With the exception of calf 4B there was good agreement between the N retentions of the calves on each diet. The N retentions obtained with diet 1 are in agreement with those given by Blaxter (1950) for whole milk. The N-retention figures have not been given for all periods, because for reasons already stated some losses of urine occurred. However, apart from calf 2A, at least one complete collection was obtained from each animal. In the main, the losses were probably not very great and the samples were, therefore, analysed for the purpose of qualitative comparisons with those from complete collections. These comparisons suggested that, in general, only slight changes in N content occurred from period 1 to period 2. With calf 4B, however, the concentration of N in its urine decreased by almost half, and resulted in the much higher retention in period 2.

Figures showing the energy derived from the digested non-protein sources have been calculated to facilitate an examination of the connexion between energy of digested nutrients and N retained.

Calcium, phosphorus and magnesium metabolism

The Ca and P of the diet were entirely supplied by the milk constituents, but about 12% of the magnesium intake came from the mineral supplement. The 'apparent percentage absorption', given in Table 5, is the apparent absorption (intake – faecal excretion) expressed as a percentage of the intake. Similarly, retention (intake – faecal and renal excretions) is also expressed as a percentage of the intake.

As generally with diets of this kind (Blaxter & Wood, 1952), the urinary excretion of Ca was low, resulting in high retention of the absorbed Ca. With P, on the other hand, although apparent absorptions were uniformly high, urinary excretions were

Table 4. *Energy digestion and nitrogen retention*

Diet no.	Trial no.	Calf	Period	Total energy intake (actual) (Cal./day)	Total energy digested (Cal./day)		Non-protein energy digested (calculated)† (Cal./day)	Nitrogen		
					Actual	Calculated*		Intake (g/day)	Apparent digestibility (%)	Retention (%)
1	1	1A	1	3248	3114	3164	2425	23·2	90·0	—
		1A	2	3248	3147	3197	2436	23·2	92·7	56·6
	2	1B	1	3382	3138	3100	2293	25·8	88·6	54·1
		1B	2	3382	3254	3198	2371	25·8	90·8	—
2	1	3A	1	3088	2706	2875	2167	23·0	87·3	36·2
		3A	2	3088	2870	3002	2280	23·0	88·9	33·0
	2	2B	1	3064	2452	2608	1969	23·6	76·7	37·6
		2B	2	3064	2805	2947	2213	23·6	88·2	—
3	1	4A	1	2402	2261	2322	1530	24·1	93·0	38·9
		4A	2	2402	2126	2205	1464	24·1	87·0	—
	2	3B	1	2350	2123	2253	1568	23·6	82·0	—
		3B	2	2350	2206	2312	1593	23·6	86·1	37·8
4	1	2A	1	3249	2537	2644	1887	24·2	87·9	—
		4A	3	3249	2648	2751	1963	24·2	91·3	35·2
	2	4B	1	3131	2416	2582	1829	24·0	88·6	—
		4B	2	3131	2401	2583	1846	24·0	86·7	50·7

* 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 5. *Metabolism of calcium, phosphorus and magnesium*

Diet no.	Trial no.	Calf	Period	Calcium: Intake (g/day)	Calcium: Apparent absorption (%)	Calcium: Retention (%)	Phosphorus: Intake (g/day)	Phosphorus: Apparent absorption (%)	Phosphorus: Retention (%)	Magnesium: Intake (g/day)	Magnesium: Apparent absorption (%)	Magnesium: Retention (%)
1	1	1A	1	5·54	91·3	—	4·28	94·4	—	0·675	51·9	—
		1A	2	5·54	94·0	92·2	4·28	96·9	72·9	0·675	54·1	52·1
	2	1B	1	5·97	76·0	75·2	4·47	88·6	67·7	0·730	36·5	30·8
		1B	2	5·97	88·7	—	4·47	94·2	—	0·730	41·8	—
2	1	3A	1	4·99	58·0	53·5	3·85	91·7	34·5	0·612	31·3	21·2
		3A	2	4·99	74·8	72·3	3·85	95·7	48·1	0·612	23·9	14·8
	2	2B	1	5·05	46·1	45·2	3·87	83·2	31·3	0·582	14·6	6·65
		2B	2	5·05	80·6	—	3·87	97·2	—	0·582	22·9	—
3	1	4A	1	5·43	90·5	79·8	3·92	97·7	64·7	0·600	66·7	45·1
		4A	2	5·43	67·6	—	3·92	93·5	—	0·600	21·4	—
	2	3B	1	5·58	65·4	—	4·17	91·3	—	0·543	33·7	—
		3B	2	5·58	67·4	63·1	4·17	92·6	52·2	0·543	39·6	26·0
4	1	2A	1	5·76	80·3	—	4·24	92·2	—	0·633	76·7	—
		4A	3	5·76	80·6	65·7	4·24	93·4	50·5	0·637	64·4	44·4
	2	4B	1	5·58	91·7	—	4·30	97·0	—	0·668	64·8	—
		4B	2	5·58	85·2	83·3	4·30	95·7	66·5	0·668	46·9	39·7

considerable, leading to lower retentions. The retention figures for Ca and P with diet 1 are in general agreement with those obtained by Blaxter & Wood (1952) with whole milk. The apparent absorption of Mg was much lower than that of Ca and P, and brought about low retention figures. In general, the retentions of Mg with diet 1 lie within the range of 30–50 % cited by Blaxter & McGill (1956) for calves. In most instances in the present trials, the urinary excretion accounted for an appreciable but variable proportion of the total Mg excretion, the extent of which is indicated by the disparity between the figures for apparent absorption and for retention. In calves 1A and 1B (diet 1) the urinary excretion of Mg accounted for about 4 and 9 %, respectively, of the total excretion, whereas with calves 4A and 3B (diet 3) the figures were 38 and 17 %. These figures may be compared with that of about 5 % given by Blaxter & Rook (1954) for calves receiving whole milk.

DISCUSSION

In assessing the role of energy supplements to skim-milk diets for calves, important criteria are the digestibility and utilization of the additives. Although the conclusions from most calf-feeding experiments have been based upon live-weight gains, and give little indication of the metabolic factors involved, they do indicate which supplements are likely to prove satisfactory in farm practice. In the majority of nutritional studies most attention has been given to fat as an energy supplement, and considerably less to carbohydrates, which may be due to the desire to simulate whole milk as closely as possible, but also to an appreciation of the desirability for a diet of high calorific value.

Energy absorption and nitrogen retention

Although in the present trials the additional intake of dry matter with diet 4 by calves 1–3 weeks old did not produce any obvious digestive upsets, there being a complete absence of scouring and a high digestibility of crude protein, the apparent digestibility of the starch in this diet was poor. Thus the energy digested was much lower than that from diet 1, to which diet 4 had been approximately equated in respect of gross energy intake. It was thought that this lower level of digested energy would result in uniformly low N retention, but calf 4B showed a surprisingly high N retention. A post-mortem examination of the stomach contents of calf 2A suggested that considerable fermentation had occurred, which makes it doubtful whether any of the starch was digested and utilized in the normal way. As the chlortetracycline apparently did not entirely suppress fermentation of the starch in diet 4, it is possible that differences in the type of fermentation may have been responsible for the differences in N retention obtained with this diet. It is, however, difficult to account for the high N retention by calf 4B during its second period, other than by assuming that the apparently digested starch was utilized to a high degree. It should be noted that this calf, although only 2–3 weeks old, had been receiving the starch diet for 11 days before this collection period. Dollar & Porter (1957) have recently reported that starch cannot be utilized by calves of less than 4 weeks old. From a recent review of the literature, Preston (1958) concludes that starch is poorly utilized by very young calves and that for the 1st month of age lactose and glucose are the only suitable carbohydrates for inclusion in a synthetic-milk diet.

In the present trials lactose was the sole source of non-protein energy in diet 3. This diet, in effect, represented a milk in which the fat had been replaced by the same quantity of lactose, resulting in the lactose content of the diet being very high (about 66 %). Although high levels of lactose are generally considered to bring about scouring (Duncan, 1955), it did not occur in the present trials. In fact, the major constituents of the diet were as well digested as those of diet 1, although the excretion of water in the faeces was greater. Despite the high digestibility of diet 3, the energy of its total digestible nutrients was inevitably lower than that of diet 1, and the retention of N was considerably less. From a review of the literature Munro (1951) concluded that when growing animals, receiving a diet adequate in protein but suboptimal in energy, are given additional fat or carbohydrate, this energy increment brings about an increased N retention. Blaxter (1950) has shown that with calves receiving milk diets lack of energy is more likely to be a limiting factor for growth than lack of protein. It would, therefore, appear that the lower N retention with diet 3 than with diet 1 was a direct reflection of the lower intake of non-protein energy.

Diet 2 differed mainly from diet 1 in containing an hydrogenated palm oil instead of butterfat, and the digestibility of the organic matter was somewhat lower. This difference was mainly due to a lower digestibility of the vegetable fat, particularly in period 1, together with a lesser lowering of the digestibility of the crude protein and N-free extractives. There was, however, a well-marked improvement in fat digestibility in the second period. Duckworth, Naftalin & Dalgarno (1950) found, with chicks initially 14 days old, a similar improvement in the digestibility of mutton fat during two successive 6-day periods, and Cunningham & Loosli (1954) observed it with lard, but not with hydrogenated coconut oil, when given to calves at 2, 4 and 6 weeks of age. In view of the improvement in fat digestibility Duckworth *et al.* obtained with chicks, and of the lack of consistency shown by calves, it seems unlikely that the increased digestibility in period 2 was due to greater efficiency of the oesophageal-groove mechanism, resulting in less spillage into the rumen during this period. As regards the factors that may influence the digestibility of a fat, Deuel (1948) found that the melting point, provided it is below 50°, has little effect on its digestibility by man, and Mattil (1946) concluded that the main factor that limits the digestibility is the amount of saturated acids present and that the degree of limitation increases with chain length.

In view of the similar amounts of non-protein energy digested by the calves receiving diets 1 and 2, it was surprising to find much poorer N retention by the calves on diet 2. It would appear that the energy supplied by the hydrogenated palm oil, although reasonably well digested, did not have the same protein-sparing effect as a similar amount of energy supplied by butterfat. In particular, with calf 3A, the increment in non-protein energy provided by the improvement in fat digestibility in the second period did not bring about any improvement in N retention.

The numerous reports of feeding trials with various types of animal and vegetable fats homogenized into a skim-milk diet, indicate large differences in the suitability of fats for calf feeding. Whereas animal fats such as lard or tallow have proved very satisfactory (Gullickson, Fountaine & Fitch, 1942; Wiese, Johnson, Mitchell & Nevens, 1947; Johnson, Hopper & Gardner, 1953; Hopper, Gardner & Johnson, 1954; Galgan & Ensminger, 1956; Ritchey, Hopper, Gardner & Johnson, 1956), some vegetable oils such as maize oil, cottonseed oil and soya-bean oil have proved unsatisfactory (Gullickson *et al.* 1942; Murley, Jacobson, Wise & Allen, 1949; Jarvis & Waugh 1949; Jacobson, Cannon & Thomas, 1949; Barker, Wise & Jacobson, 1952). Although with soya-bean oil, hydrogenation brings about a marked improvement (Jacobson & Cannon, 1947; Murley *et al.* 1949; Jacobson *et al.* 1949; Barker *et al.* 1952), the live-weight gains are not quite so good as with butterfat. With cottonseed oil Jarvis & Waugh (1949) found that hydrogenation brings about only a small improvement. With rats Aaes-Jørgensen & Dam (1954*a*) found that a variety of hydrogenated fats markedly depressed growth rates as compared with unhydrogenated fats. They have also shown (Aaes-Jørgenson & Dam 1954*b*) that supplementation of an hydrogenated fat with linoleic acid brings about a significant improvement.

It would appear that in our trials the poor protein-sparing effect of the hydrogenated palm oil as compared with butterfat could be explained, at least partly, by its lack of unsaturated fatty acids. This reduction in protein-sparing effect brought about by hydrogenation is supported by the findings in subsequent trials, the results of which will be reported in due course, in which N retention has been used to study the value of different fats as sources of energy in calf diets. In relation to the N-balance technique, it should be noted that Blaxter (1950) has shown a very close relationship between the rate of gain of body N and of body-weight. Therefore, this method would appear to offer a means of assessing the value of different fats for calf diets and at the same time provide information about the nutritional factors involved.

Mineral metabolism

It is generally recognized that the retentions of Ca, P and Mg are very much a function of general growth (Owen, 1952). Thus it was to be expected that the retention of these elements would be related to the retention of N, which seems to have been the general trend. Some exceptions were noted. The relatively poor absorption of Ca and Mg by calf 1 B in period 1 was apparently related to a correspondingly high fatty-acid content of the faeces. This trend was even more marked with both the calves on diet 2. The loss of Ca as Ca soaps in conditions of abnormal fat digestibility has been mentioned by Owen (1952); presumably Mg can be similarly affected. As the P requirements of the animal are closely related to its Ca requirements, changes in Ca retention are likely to bring about corresponding changes in P retention, which appears to have happened.

Lactose is generally credited with being favourable to Ca retention, but such an effect has not been evident with diets 3 and 4. It seems reasonable to suppose that all the diets contained sufficient lactose to create these favourable conditions. With diet 4 in particular, calf 4B in period 2 showed a high retention of Ca and P, which would appear to be more related to its unexpectedly high N retention than to any other dietary factor.

SUMMARY

1. Two similar trials involving nitrogen and mineral balances, each with four calves, were carried out to compare the nutritive value of reconstituted whole milk with that of three modified-milk diets in which the source and quantity of non-protein energy were varied. The trials began when the calves were about 1 week old.

2. The digestibility of an hydrogenated palm oil increased from 76 to 92% during two consecutive 6-day periods, as compared with an average digestibility of 96% obtained with butterfat. Even when the digestibility of the palm oil was of the same order as that of the butterfat the palm oil exhibited a much poorer protein-sparing effect as assessed by N retention, which suggests that utilization of the hydrogenated oil as a source of energy was poor.

3. The replacement of butterfat by lactose, weight for weight, which resulted in a much lower intake of energy, was accompanied by a much poorer retention of N. Maize starch added to the high-lactose diet had an apparent digestibility of only about 50%. The utilization of this apparently poorly digested starch was variable as judged by its effect on N retention.

4. The retention of calcium, phosphorus and magnesium was, as expected, closely related to the retention of N. It was, however, indirectly affected by the digestibility of the fat. The undigested fat, particularly the hydrogenated palm oil, was hydrolysed in the alimentary tract, and the resultant increase in the output of fatty acids was related to an increased faecal excretion of Ca and Mg.

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