The effect of increasing amounts of dietary red palm oil on milk fat secretion in the cow

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1. The effects, on the secretion in milk of fat and its component fatty acids, of supplementing a basal diet low in fat with red palm oil at three levels are reported.

2. The secretion of total fat and of the fatty acids contained in the oil supplement was positively correlated with the dietary intakes, except for linoleic acid which was hydrogenated in the rumen before its absorption and secretion in milk.

3. Evidence for the synthesis *de novo* of palmitic acid and for the possible depression of intramammary *de novo* synthesis by high levels of dietary fat is discussed.

Previous studies have shown that addition of either coconut, red palm or groundnut oil to a basal diet low in fat increased the secretion in cow's milk of both total fat and the major fatty acids characteristic of these oil supplements (Storry, Rook & Hall, 1967). In the present paper the effects of supplementing a low-fat diet with various amounts of red palm oil on the secretion of milk fat are presented.

EXPERIMENTAL

Animals and their management. Four Friesian cows in the 2nd month of lactation were fed a diet of meadow hay (5 kg), sugar-beet pulp (5 kg) and a basal concentrate mixture. The basal concentrates consisted of barley (21·8%), rice (16·3%), tapioca (16·3%), decorticated groundnut meal (32·7%), blood meal (10·9%) and minerals (2·0%). To the basal concentrates red palm oil was added at approximately 2%, 4% and 8% (w/w) to give three experimental concentrate mixtures. The ether extract values for the basal and three oil-supplemented concentrate mixtures were 0·94, 2·81, 4·95 and 8·85% respectively, and the corresponding gross energy contents, as determined by bomb calorimetry, 3·95, 4·06, 4·21 and 4·48 kcal/g. The basal concentrate mixture was fed according to yield at the rate of 0·4 kg/kg milk and the oil-supplemented mixtures at corresponding isocaloric rates.

Procedure. The experimental design was a balanced 4 × 4 Latin square, with periods of 22 days. The effects of the oil supplements on the yield of total milk fat were assessed from a simple over-all regression of yield on intake of fat from the concentrate food calculated from the pooled results for all cows for the last 12 days of the feeding periods. The yields of individual fatty acids in milk during the last 12 days of the feeding periods were first analysed according to an ordinary analysis of variance for Latin squares (Snedecor, 1950). Carry-over effects from one diet to the next would not have persisted into the last 12 days of the feeding periods since the effects of dietary oil supplements on the composition of milk fat are fully established within

6 days of the introduction of the oil supplement (Storry *et al.* 1967). When the yield of individual fatty acids increased in association with increased dietary intake of the acid, simple over-all regressions of yield on dietary intake were also calculated from pooled values for all cows.

The content and composition of milk fat were determined as previously described (Storry *et al.* 1967).

RESULTS

Yields of milk and milk fat. The mean effects of the red palm oil supplements on the yield of milk and on the percentage and yield of milk fat for the first 10 and last 12 days of the feeding periods are given in Table 1. During the first 10 days there was

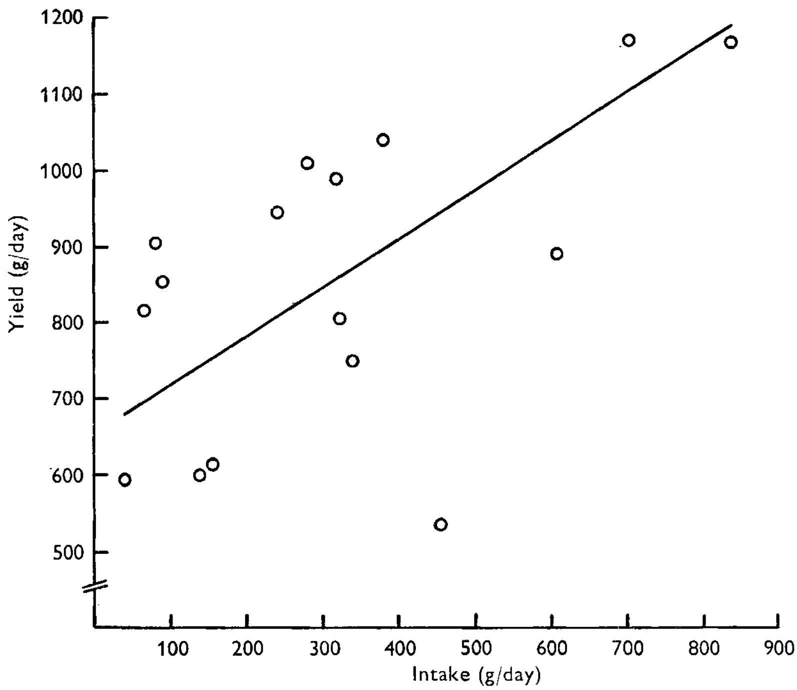

Fig. 1. Regression of milk fat yield of cows on the intake of fat from the concentrate food for the last 12 days of the feeding periods. The line represents the regression of milk fat yield on the intake of fat.

no effect on milk yield, but the content and yield of milk fat increased with increased dietary intake of red palm oil. During the last 12 days of the feeding periods the yield of milk fat also increased with increased intake of red palm oil but there was no increase in milk fat content because of a concomitant increase in milk yield. The regression of milk fat yield on the intake of fat derived from the concentrate food is given in Fig. 1 and the regression coefficient ($b = 0.64 \pm 0.142$) was highly significant.

Secretion of fatty acids in milk. The fatty acid compositions of the control concentrate and of the three concentrates supplemented with red palm oil at different levels are given in Table 2 and the mean effects of these foods on the yields of the major

Table 1. *Effect of dietary supplements of red palm oil* on the percentage and yield of milk fat and on the yield of milk by cows*

Oil supplement	Milk yield (kg/day)	Milk fat content (%)	Yield of milk fat (g/day)
	First 10 days of each period		
None	23·09	3·54	834
Low	22·37	3·64	810
Medium	22·73	4·01	924
High	23·58	4·33	1032
	Last 12 days of each period		
None	20·49	3·85	792
Low	21·11	3·75	792
Medium	21·85	4·09	897
High	24·02	3·88	942

* Approximately 2 %, 4 % or 8 %.

Table 2. *Fat content (%) and fatty acid composition (%) of the concentrate foods*

Constituent	Control	Low supplement	Medium supplement	High supplement
Ether extract	0·94	2·81	4·95	8·85
Fatty acid*				
14:0	—	tr	1·0	1·0
16:0	21·5	42·0	43·9	44·7
18:0	3·4	3·4	2·7	3·1
18:1	37·6	38·0	39·0	38·5
18:2	37·4	15·8	13·4	12·5

tr, trace.
* Number of carbon atoms and number of double bonds (Farquhar, Insull, Rosen, Stoffel & Ahrens, 1959).

Table 3. *Effect of dietary supplements† of red palm oil on the yields (g/day) of the major fatty acids in milk of cows*

Fatty acid‡	Control	Low supplement	Medium supplement	High supplement
4:0	24·1	24·1	27·5*	34·4*
6:0	18·0	19·4	19·6	20·8
8:0	12·2	12·2	12·9	13·1
10:0	30·3	29·5	26·9	23·9
12:0	42·9	39·3	35·3	29·5
14:0	110·5	102·6	101·5	93·8
16:0	285·3	262·9	291·0	318·5
18:0	25·1	34·8	55·8**	58·7**
18:1	103·7	129·9	169·9**	206·6***
18:2	8·4	7·3	7·5	7·4

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$, where P is the probability that the observed difference from the control value could have arisen by chance.
† Approximately 2 %, 4 % or 8 %.
‡ See footnote to Table 2.

fatty acids in milk in Table 3. Supplementation of the diet with palm oil progressively increased the dietary intakes of palmitic, stearic, oleic and linoleic acids which, with the exception of linoleic acid, were associated with increased yields of the corresponding acids in milk. Also the yield of butyric acid increased significantly and the yields of capric, lauric and myristic acids tended to decrease with the medium and high oil supplements. Regressions of the yields of palmitic, stearic and oleic acids on the dietary intakes of the respective acids are shown in Fig. 2. The regression coefficient values for palmitic ($b = 0.54 \pm 0.129$), stearic ($b = 2.57 \pm 0.437$) and oleic ($b = 0.65 \pm 0.089$) acids were highly significant.

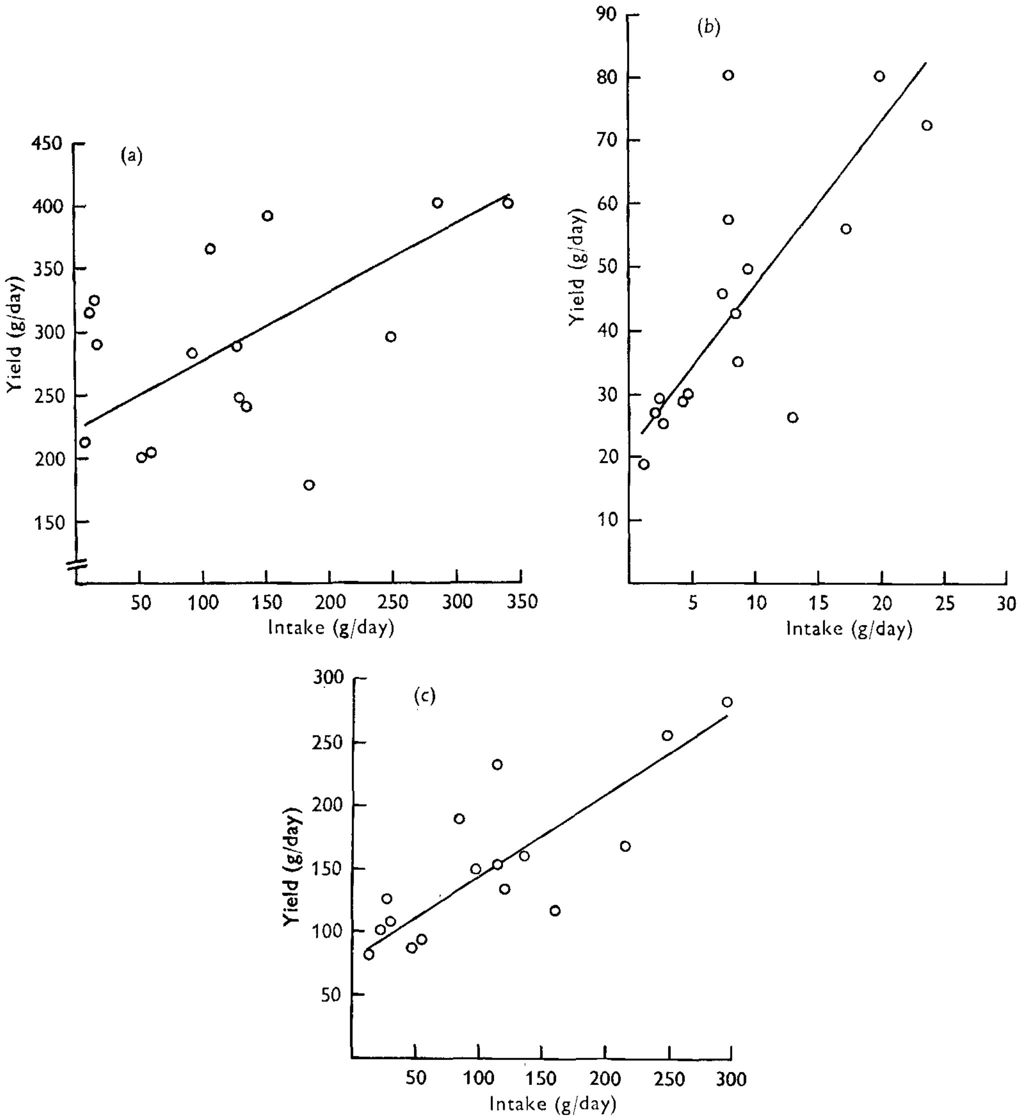

Fig. 2. Regression of yield in cow's milk of (*a*) palmitic acid, (*b*) stearic acid and (*c*) oleic acid on its intake from the concentrate food during the last 12 days of the feeding periods. The lines represent the regressions of yield on intake for the various acids.

Because the concentrates were fed according to yield and refusals were taken into account, the dietary intake of acids by individual cows on a particular concentrate varied, and this was particularly so with the highest oil supplement. The increased yields of palmitic acid were relatively much smaller than the increased yields of stearic and oleic acids and they only became significant in the regression analysis when the intakes of palmitic acid by individual animals were taken into account.

DISCUSSION

The increased content and yield of fat in milk during the early part of the feeding period in association with the increased dietary intake of red palm oil fully confirms previous findings (Storry *et al.* 1967), and the significant regression of milk fat yield on intake of dietary fat during the last 12 days of the feeding periods confirms the positive influence of dietary fat on milk fat secretion. The effects of the oil supplements on the yield of total milk fat tended to be more marked during the first 10 than during the last 12 days of the feeding periods, which may be a reflection of adaptive changes in digestion (Czerkawski, 1966) or milk fat synthesis by the animal. A similar effect of time on the response in milk fat yield to dietary supplements of tallow and cottonseed oil has also been observed by Steele & Moore (1968). The oil content of the concentrate food with the medium supplement of palm oil was of the same order as the oil content of many commercial concentrate mixtures for lactating cows, whereas that of the ration with the high oil supplement was considerably greater than the oil content of certain proprietary 'oil-rich' concentrate mixtures. It would appear that further increases in the yield of milk fat could be achieved with intakes of dietary fat even higher than those used in the present experiments provided that no adverse effects on palatability or digestion of the food resulted.

With the exception of linoleic acid, the yields of the individual long-chain fatty acids in milk were positively correlated with the dietary intakes of the respective acids. The absence of an increased yield of linoleic acid, in spite of an increased intake of this acid, is in line with findings of earlier workers (Brown, Stull & Stott, 1962; Tove & Mochrie, 1963; Parry, Sampugna & Jensen, 1964; Storry *et al.* 1967) and is doubtless accounted for by hydrogenation of linoleic acid to oleic and stearic acids in the rumen (Garton, 1965, 1967). The significance of this hydrogenation is also apparent in the results for stearic acid, where the high value of 2·57 for the regression coefficient indicates that some of the stearic acid in milk fat must have been derived from sources other than stearic acid in the diet.

The linear relationship between the yield of oleic acid in milk and the dietary intake of oleic acid obtained in the present experiments confirms the increased yields of oleic acid obtained in other experiments with the intravenous infusion of triolein into lactating cows (Storry, Tuckley & Hall, 1969). However, although this relationship between oleic acid in the diet and in milk fat was observed, it must be remembered that oleic acid in milk can be derived not only directly from oleic acid in the diet but also indirectly from linoleic acid after partial hydrogenation in the rumen and from stearic acid by dehydrogenation in the mammary gland (Lauryssens, Verbeke & Peeters, 1961; Annison, Linzell, Fazakerley & Nichols, 1967).

In contrast to our earlier findings, the secretion of palmitic acid in milk increased with increased dietary intake of this acid. This apparent discrepancy may possibly be related to the longer feeding periods and the higher dietary intakes of palmitic acid in present experiments.

Although the fatty acid compositions of the sugar-beet pulp and hay were not determined in the present experiment, feeding the same quantities of hay and sugar-beet pulp to cows in a previous experiment contributed together approximately 20, 10 and 5 g of palmitic, oleic and stearic acids respectively to their daily intake of these acids. On the assumption that contributions from the hay and sugar-beet pulp to the dietary intakes of palmitic, oleic and stearic acids were similar in the present experiments, extrapolation of the calculated regressions to true zero dietary intake gives values for yields in milk of palmitic, oleic and stearic acids of 212, 72 and 9 g respectively. This much higher value for the yield of palmitic acid compared with that of the C_{18} acids is interesting in view of the known fact that palmitic acid, in contrast to the C_{18} acids, of milk is derived not only from the preformed triglyceride of blood plasma β-lipoproteins (and hence from dietary palmitic acid) but also by synthesis *de novo* within the alveolar cells from acetate and β-hydroxybutyrate (Barry, 1964).

In addition to changes in the yields of the long-chain acids in milk, the increased intake of red palm oil was associated with an increased yield of butyric acid and decreased yields of capric, lauric and myristic acids. This pattern of response in the secretion of the short- and intermediate-chain acids in milk was also observed in a previous experiment (Storry *et al.* 1967), and these changes may reflect reduced fatty acid synthesis within the mammary gland similar to that observed in in vitro studies with rat (Coniglio & Bridges, 1966) and bovine (Hibbit, 1966) mammary gland.

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