Artificial rearing of pigs

4.* The replacement of butterfat in a whole-milk diet by either beef tallow, coconut oil or soya-bean oil

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1. The butterfat in a whole-milk diet was replaced by either beef tallow, coconut oil or soya-bean oil. The diets contained 280 g fat and 720 g dried skim milk per kg and were supplemented with vitamins A, D, E and K.

2. These diets were offered as a milk, containing 200 g solids/kg, to pigs weaned at 2 d of age during a 26 d experiment. The pigs were fed at hourly intervals to a scale based on live weight (scale *E*).

3. The performance of the pigs and the apparent digestibility of the dietary fats indicated that soya-bean oil was equal to butterfat. Butterfat was slightly superior to coconut oil and markedly superior to beef tallow.

4. The amount and composition of the fatty acids were studied in the proximal, mid and distal portions of the small intestine. When the beef tallow diet was given there was an increased amount of total fatty acids in the digesta of the small intestine, mainly in the distal portion. The digesta contained the smallest quantity of fatty acids when the soya-bean oil diet was given. The fatty acid composition of the digesta indicated that the short- and medium-chain fatty acids from all the diets were well utilized, but an increasing proportion of stearic acid occurred in the distal portion of the small intestine. The interpretation of changes in fatty acid composition in the digesta in relation to absorption is discussed.

Although baby pigs can be reared successfully on a whole-milk diet (Braude, Mitchell, Newport & Porter, 1970; Braude, Newport & Porter, 1971), such a diet is uneconomical, and the replacement of butterfat by cheaper fats would be a desirable step towards the development of an economic diet. Liquid diets containing skim milk and fat are well utilized by calves (Raven, 1970; Roy, Stobo, Gaston & Greatorex, 1970; Veen, 1970) and lambs (Walker & Stokes, 1970), but the utilization of such diets by baby pigs has received little attention, although Cunningham & Brisson (1955) and Manners & McCrea (1963) have reported that 2-d-old pigs could be reared on diets containing lard.

Pigs have been weaned at 14–21 d of age on to dry diets given *ad lib.* and containing different fats. In such experiments the apparent digestibility of butterfat and coconut oil was shown to be greater than that of beef tallow or soya-bean oil (Lloyd & Crampton, 1957; Crampton, Shaw, Mackay & Schad, 1960) but no difference was found between the digestibilities of beef tallow and coconut oil (Hamilton & McDonald, 1969) or between those of butter, soya-bean oil or coconut oil (Frobish, Hays, Speer & Ewan, 1970). Butterfat supported better weight gains than did coconut oil (Crampton *et al.* 1960), or either coconut oil or soya-bean oil (Frobish *et al.* 1970). Eusebio, Hays,

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Speer & McCall (1965) found little difference in utilization between beef tallow, coconut oil and soya-bean oil.

In this paper the utilization of butterfat, beef tallow, coconut oil and soya-bean oil by pigs weaned on to a liquid diet at 2 d of age is reported.

EXPERIMENTAL

Diets and method of feeding

The diets were prepared from a single bulked sample of whole cow's milk, a portion of which was spray-dried, and the remainder separated. Mixtures of skim milk with butterfat, beef tallow, coconut oil and soya-bean oil were also spray-dried. The dried powders contained 10 g lecithin and 14 mg butylated hydroxytoluene/kg, added before spray-drying. Each of the five diets contained 270 g crude protein (nitrogen × 6·38) and 280 g fat per kg dry matter. The non-casein N (NCN) was 17 % of the total N.

Liquid diets containing 200 g solids/kg were prepared from the dried powders. Batches of diet were prepared twice weekly by homogenization of the reconstituted milk at a pressure of 176 kg/cm^2 followed by pasteurization at 72° for 17 s. The diets were supplemented with Rovisol AD$_3$E Oral, DL-α-tocopheryl acetate (Roche Products Ltd, London) and menaphthone (Koch-Light Laboratories Ltd, Colnbrook) to supply the following amounts (per kg dry matter): 0·6 mg retinol; 5 μg cholecalciferol; 1·65 mg α-tocopherol and 62 μg menapthone. The diets were stored at 4°. Before use, formalin (0·5 ml/l) was added as preservative.

The experimental routine described by Braude *et al.* (1970) was followed, with the modification that feeding equipment was cleaned and refilled with fresh diet once, instead of twice, daily.

The pigs were fed to scale, at hourly intervals, according to live weight. During the first few days, low levels of feeding (scales *A* and *B*) were used, gradually increasing to a higher level (scale *C*) (Braude *et al.* 1970). This modified scale (scale *E*) is shown in Fig. 1. No additional water was supplied.

Experimental design

Litter-mate 2-d-old pigs were allocated to the five treatments on the basis of live weight and sex. The pigs on different treatments were kept in separate rooms, each room containing four replicates. This procedure was repeated three times, that is there were twelve pigs/treatment. The pigs were on experiment from 2 to 28 d of age.

N retention

The method described by Braude *et al.* (1970) was used. Collection periods were of 4 d duration.

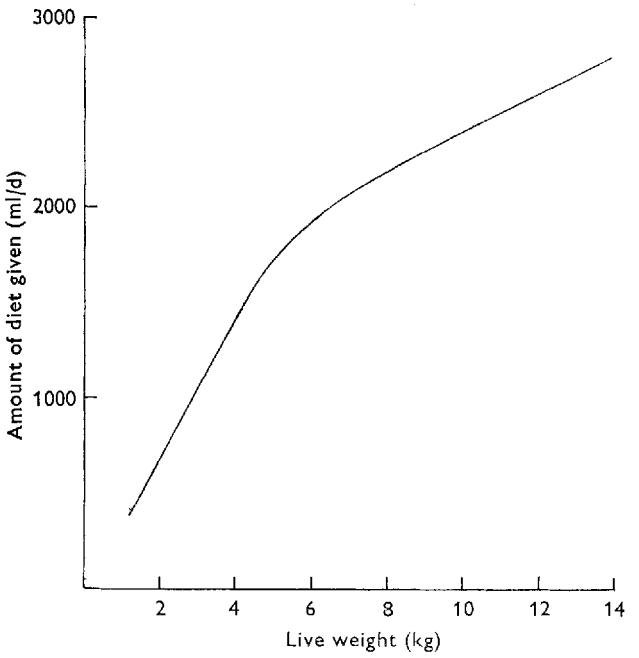

Fig. 1. Scale *E* for feeding baby pigs. The milk contained 200 g solids/kg.

Procedure at slaughter

The pigs were killed at 28 d of age, 1 h after a feed. The procedure of Braude *et al.* (1970) was followed, with the exceptions that analyses were carried out on whole digesta without separation into soluble and insoluble fractions, and no investigations were made on the caecal contents. Digesta from each pig were collected from three approximately equal portions of the small intestine and freeze-dried before analysis.

The whole carcass minus the alimentary tract was homogenized and a sample was freeze-dried. The preparation of samples for chemical analysis has been described elsewhere (Florence & Mitchell, 1972).

Analytical methods

Dry matter and total N were estimated by the methods described by Braude *et al.* (1970). Ash was determined by weighing the residue after heating at 540° for 17 h. The method of Rowland (1938) was followed for the estimation of NCN.

Total lipids in samples of ground, freeze-dried digesta, faeces and dry diet were extracted for 6 h with chloroform–methanol (2:1 by volume) in a Soxhlet apparatus. The extracted lipids were made up to a known volume (250 ml) with more chloroform–methanol and washed with 50 ml of potassium chloride solution (8·8 g/l) as described by Folch, Lees & Stanley (1957). The lipids were recovered from the lower solvent phase and dried to constant weight under a stream of N_2. The solvents used for the lipid extraction and fatty acid analysis were redistilled before use.

Total fatty acids were obtained from the lipid extract by hydrolysis with potassium

Table 1. *Performance of pigs given diets of whole milk or skim milk containing butterfat, beef tallow, coconut oil or soya-bean oil*

Diet	2–7 d old		2–28 d old	
	Live-wt gain (g/d)	Feed/gain†	Live-wt gain (g/d)	Feed/gain†
Whole milk	219	0·59	387	0·82
Skim milk: + butterfat	224	0·57	401	0·81
+ beef tallow	199*	0·64*	377*	0·83
+ coconut oil	204*	0·62	381*	0·82
+ soya-bean oil	197*	0·65*	394	0·79
Standard error of mean	4·4 (44 df)	0·019 (44 df)	6·1 (41 df)	0·010 (41 df)

* Significantly worse ($P < 0·05$) than value for skim milk plus butterfat.
There were twelve pigs/treatment with a mean initial weight of 1·69 kg. Three pigs receiving the skim milk plus soya-bean oil died between 7 and 28 d age. Adjustments were made for missing values.
† g milk solids/g live-wt gain.

Table 2. *Carcass weight and proportions of dry matter, crude protein, total lipid and ash for 28-d-old pigs given diets of whole milk or skim milk containing butterfat, beef tallow, coconut oil or soya-bean oil*

(Mean values for six pigs/treatment)

Diet	Wt (kg)*	Dry-matter content (g/kg)	Crude protein† (g/kg dry matter)	Total lipid (g/kg dry matter)	Ash (g/kg dry matter)
Whole milk	11·1	380	373	515	88
Skim milk: + butterfat	11·4	370	391	526	92
+ beef tallow	10·6	365	397	509	91
+ coconut oil	10·7	373	386	524	95
+ soya-bean oil	11·4	377	373	520	86
Standard error of mean (20 df)	0·27	5·8	10·4	7·8	2·1

None of the differences between diets were significant ($P > 0·05$).
* 91–93 % of the live weight.
† $N \times 6·25$.

hydroxide solution (30 g/l) and extracted according to the procedure of Lough, Navia & Harris (1966), using hexane in place of light petroleum. The extracted fatty acids were dried to constant weight under a stream of N_2.

Methyl esters of the total fatty acids were prepared with boron trifluoride–methanol complex containing 14 % BF_3 (British Drug Houses Ltd, Poole, Dorset) under reflux (Metcalfe & Schmitz, 1961). The composition of the esters was determined by gas–liquid chromatography in a Hewlett–Packard 7620 chromatograph fitted with dual flame ionization detectors and packed metal columns (1·83 m × 3·2 mm) of polyethylene glycol adipate (20 g/l) coated on 80/100 mesh acid- and alkali-washed Celite. The detection system was calibrated with authentic methyl esters for quantitative analysis. The peaks on the chromatogram were identified by reference to chromatograms of authentic methyl esters.

Table 3. *Apparent digestibility of total lipid and dry matter, and N retention of pigs given diets of whole milk or skim milk containing butterfat, beef tallow, coconut oil or soya-bean oil*

Diet	Apparent digestibility ratio		N retention (g/d per kg live wt)	
	Total lipid	Dry matter	At 6 d age	At 26 d age
Whole milk	0·963	0·975	2·62	1·26
Skim milk: + butterfat	0·966	0·979	2·54	1·30
+ beef tallow	0·938*	0·964†	2·51	1·14*‡
+ coconut oil	0·983	0·989	2·55	1·27
+ soya-bean oil	0·972	0·984	2·65	1·54
Standard error of mean§	0·0070 (8)	0·0043 (8)	0·134 (4)	0·079 (4)

* Significantly worse ($P < 0·05$) than for all other diets.
† Significantly worse ($P < 0·05$) than values for skim milk plus coconut oil or plus soya-bean oil.
‡ Significantly worse ($P < 0·05$) than value for skim milk plus soya-bean oil.
§ Figures in parentheses are the number of observations.

Table 4. *Dry matter and lipid content, and pH value of digesta from the stomach of 28-d-old pigs given diets of whole milk or skim milk containing butterfat, beef tallow, coconut oil or soya-bean oil*

(Mean values for seven pigs/treatment)

Diet	Dry matter (g)	Total lipid (g)	pH
Whole milk	12·0	7·2	4·3
Skim milk: + butterfat	10·4	5·4	3·6
+ beef tallow	11·3	7·8	4·1
+ coconut oil	15·8	7·9	3·6
+ soya-bean oil	18·1	9·6	3·7
Standard error of mean (22 df)	3·29	1·68	0·29

The differences between treatments were not significant ($P > 0·05$).
One missing value was calculated for the whole milk and skim-milk + soya-bean oil diets.

RESULTS

Performance and carcass composition

The performance of the pigs is given in Table 1. In comparison with whole milk, the removal and replacement of butterfat had no effect on the performance of the pigs. During the 1st week of life butterfat was superior to the other fats, but over the whole experimental period only coconut oil and beef tallow resulted in slight depressions in growth rate. The deaths of three pigs receiving the soya-bean oil diet did not appear to be related to the use of this fat.

There were no significant differences between treatments in the amounts of dry matter, crude protein, total lipid and ash in the carcass (Table 2). In parallel with the growth rate, carcass weights were slightly less for pigs given the coconut oil and beef tallow diets, although the differences were not significant at the $P = 0·05$ level.

Table 5. *Total fatty acid content (g) of the digesta from the proximal, mid, and distal portions of the small intestine of 28-d-old pigs given diets of whole milk or skim milk containing butterfat, beef tallow, coconut oil or soya-bean oil*

(Mean values for seven pigs/treatment)

Diet	Proximal	Mid	Distal	Total
Whole milk	0·70	0·38	0·50	1·58
Skim milk: + butterfat	0·49	0·79	0·40	1·68
+ beef tallow	0·54	0·46	0·89	1·89
+ coconut oil	0·49	0·62	0·32	1·43
+ soya-bean oil	0·34	0·38	0·43	1·15

The difference between means for diets and portions of small intestine were not significant ($P > 0·05$). The standard error of a portion mean was 0·086 (60 df), and of a total fatty acid mean it was 0·259 (24 df). The standard error of a difference between portions within a diet was 0·270 (60 df) and between diets within a portion it was 0·252 (60 df).

Apparent digestibility of total lipid and dry matter, and N retention

The apparent digestibility of both total lipid and dry matter was high for all diets. The apparent digestibility of total lipid in the beef tallow diet was lower ($P < 0·05$) than in all the other diets, and that of its dry matter lower ($P < 0·05$) than in the coconut or soya-bean oil diets. The apparent digestibility of either lipid or dry matter did not differ with age, and the results in Table 3 are mean values for pigs taken at 6 and 26 d of age. N retention was higher at 6 than at 26 d of age. The soya-bean oil diet promoted a greater N retention at 26 d of age than the beef tallow diet ($P < 0·05$).

Composition of digesta in the stomach

The amount of dry matter, total lipid and the pH value in the stomach digesta did not vary with the type of fat in the diet (Table 4). About half of the dry matter in the stomach digesta was present as lipid, compared with 28% in the diet.

Composition of digesta in the small intestine

The total fatty acid content of the proximal and mid region of the small intestine was unaffected by the type of fat in the diet. However, the distal portion had an increased fatty acid content when the beef-tallow diet was given (Table 5).

The fatty acid composition of the digesta from the three regions of the small intestine is given in Fig. 2, and for comparison the fatty acid composition of the diets is also shown. Only the more important fatty acids are shown, that is those constituting more than 5% of the total fatty acids in at least one of the diets. As the results for whole milk and skim milk plus butterfat diets were nearly identical, only those for the latter diet are presented.

In the butterfat diets 8% of the total fatty acids contained ten carbon atoms or fewer, and the absence of these from the digesta suggested that they were readily absorbed. The decreasing proportion of lauric acid also indicated that it was readily absorbed from these diets. The digesta contained a greater proportion of stearic acid

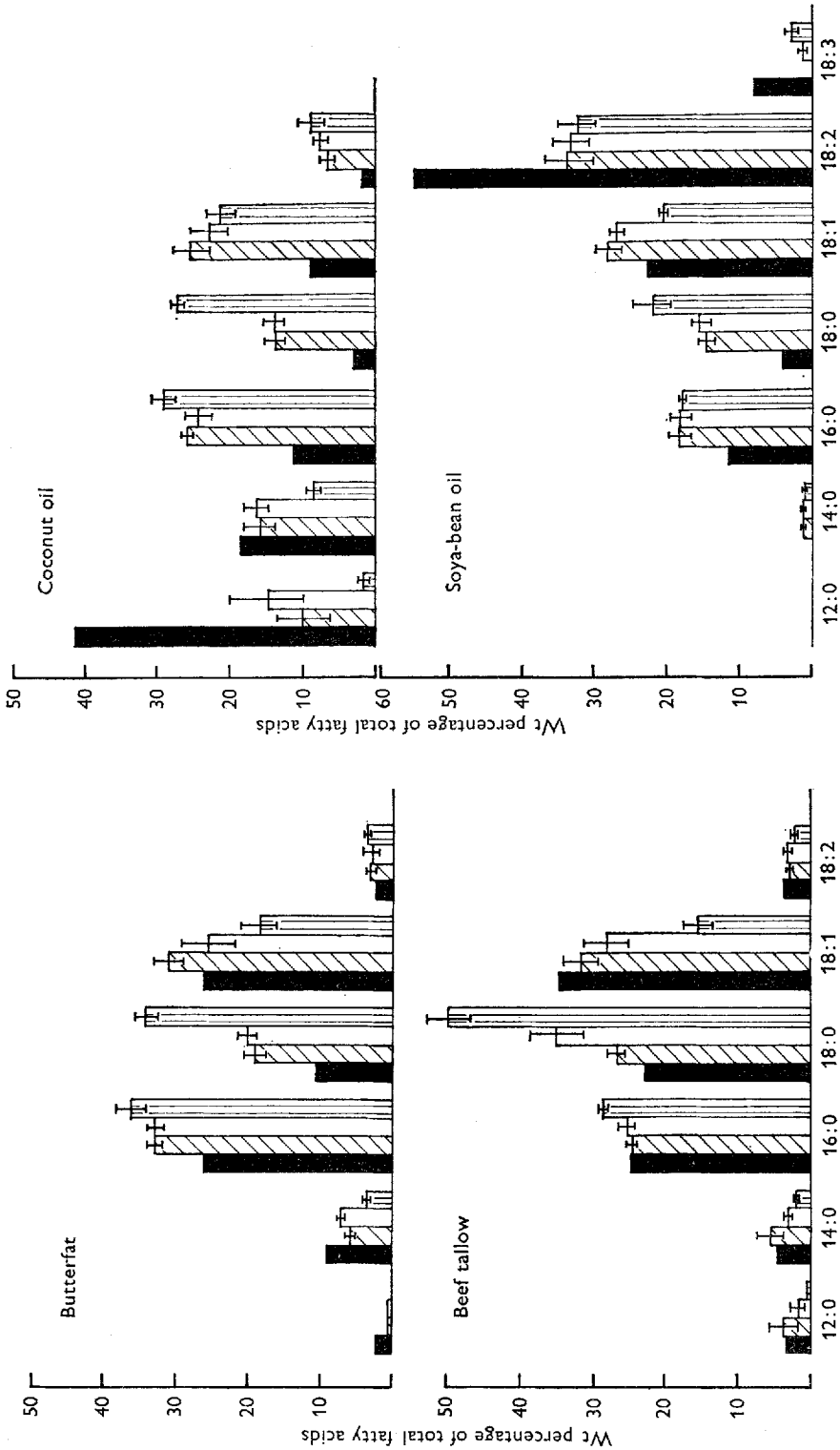

Fig. 2. Fatty acid composition of the diets and digesta from the proximal, mid and distal portions of the small intestine of 28-d-old pigs given diets of skim milk containing butterfat, beef tallow, coconut oil or soya-bean oil. Histograms are mean values for four pigs, the vertical bars represent the standard errors of the mean. ■, diet; ▨, proximal small intestine; □, mid small intestine; ▥, distal small intestine.

in the total fatty acid fraction than the diets, and hence this fatty acid appeared to be less readily absorbed. The proportion of oleic acid in the total fatty acid fraction, but not that of linoleic, decreased distally along the small intestine. Linoleic acid, which is the major fatty acid in soya-bean oil, was present in a much lower proportion in the fatty acids in the digesta from the small intestine than in the diet.

DISCUSSION

During the 1st week of life the performance of the pigs given the butterfat diets was superior to that of the pigs given either beef tallow, coconut oil or soya-bean oil. During this period the retention of N was unaffected by the type of fat in the diet. Over the entire experiment, until 28 d of age, the weight gain of the pigs was slightly poorer when the coconut oil or beef tallow diet was given, but the gain with soya-bean oil was equal to that with butterfat. Apparent digestibility of the fat and N retention were also less on the beef tallow diet. The dietary fat had little influence on carcass composition, which was to be expected from the similarity in the performances on the different diets.

The amounts of total fatty acids in the digesta from the small intestine were greater when the beef tallow diet was given, indicating a poorer utilization of this fat, in agreement with the performance and digestibility results. The digesta from pigs receiving the soya-bean oil diet, which was utilized as efficiently as the butterfat diet, contained the lowest amount of fatty acids. Thus, the amount of fatty acids in the digesta may be related to the performance of the animals.

The patterns of the fatty acids in the digesta indicated that short- and medium-chain fatty acids were most readily, and stearic acid least readily, absorbed. Frobish, Hays, Speer & Ewan (1971) reported that pancreatic lipase from baby pigs hydrolysed glycerides containing short-chain fatty acids (tributyrin) and medium-chain fatty acids (butter and coconut oil) more readily than those containing predominantly long-chain fatty acids (lard). The changes in the fatty acid pattern in the small intestine toward an increased proportion of stearic acid (Fig. 2) were more marked than those reported by Carlson & Bayley (1968) for pigs given diets containing either maize oil, lard or tallow.

The dietary fats had a high apparent digestibility (Table 3), and were well absorbed. In the pig most of the fat is absorbed in the upper portion of the small intestine (McDonald & Sullivan, 1971). Therefore changes in the pattern of fatty acids in the distal region of the small intestine will not reflect to any extent the total absorption of the dietary fatty acids. Under these circumstances, caution must be exercised in the interpretation of changes in the fatty acid composition of the digesta in the distal small intestine.

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