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Artificial rearing of pigs

5*. The effect of different proportions of beef tallow or soya-bean oil and dried skim milk in the diet on growth, feed utilization, apparent digestibility and carcass composition

By R. BRAUDE, H. D. KEAL AND M. J. NEWPORT

National Institute for Research in Dairying, Shinfield, Reading RG2 9AT

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1. Diets containing different proportions of skim milk and fat, either beef tallow or soya-bean oil, supplemented with fat-soluble vitamins were given to 2-d-old pigs. Each fat source was used in three diets containing approximately 280, 350 and 420 g fat, and 260, 235 and 210 g protein/kg dry matter respectively.

2. The diets were given as a milk containing 200 g solids/l during a 26 d experiment. The pigs were given the diet at hourly intervals according to a scale based on live weight.

3. Increasing the energy content of the diet, with the accompanying decrease in protein content, had no effect on live-weight gain or feed:gain ratio (g feed dry matter/g live-weight gain) (other than a slight reduction in live-weight gain when beef tallow was used), or on nitrogen retention. However, the fat content of the carcass of the 28-d-old pig was increased, and its protein and ash content were decreased.

4. The apparent digestibilities of the fatty acids ranged from 0·96 to 1·00. The faeces from pigs given the soya-bean-oil diets contained some eicosanoic, docosanoic and tetracosanoic acids, presumably of bacterial origin. In general, palmitic and stearic acids were slightly less well digested than oleic and linoleic acids.

Whole cow's milk is an excellent substitute for sow's milk for pigs weaned at 2 d of age (Braude, Mitchell, Newport & Porter 1970), but it is not economical to use nor is it available commercially in large enough quantities. The replacement of butterfat by other fats could provide a cheaper source of dietary energy.

In a previous experiment soya-bean oil was utilized as a source of energy as efficiently as butterfat by baby pigs given liquid diets based on skim milk, but beef tallow was somewhat inferior (Braude & Newport, 1973). These diets contained 270 g protein (provided by 730 g dried skim milk) and 270 g fat/kg diet. The object of the present work was to study the possibility of including a greater proportion (335 or 400 g/kg diet) of fat, either soya-bean oil or beef tallow, in liquid diets for artificially reared pigs.

Sow's milk, which contains about 400 g fat/kg dry matter (DM) (Braude, Coates, Henry, Kon, Rowland, Thompson & Walker, 1947), had an apparent digestibility for fat of 0·95 in a study with 2-d-old pigs (Frobish, Hays, Speer & Ewan, 1967). Therefore, provided the diet is adequate with respect to other nutrients, the baby pig should be capable of efficient digestion of a high-fat diet. However, increasing the energy content at the expense of the protein content of the diet, as in the present experiment, can reduce live-weight gain of the pigs and increase the fat content of the carcass (Schneider & Sarett, 1966). When the protein content in the diet was maintained, the

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Table 1. *Composition of the fat-supplemented, skim-milk diets given to pigs*

Fat source ...	Beef tallow			Soya-bean oil		
Level of fat ...	Low	Medium	High	Low	Medium	High
Ingredients (g/kg diet)						
Dried skim milk	730	665	600	730	665	600
Beef tallow	270	335	400	—	—	—
Soya-bean oil	—	—	—	270	335	400
Chemical composition						
Crude protein (nitrogen × 6·25) (g/kg DM)	264	237	210	261	236	209
Total lipid (g/kg DM)	280	352	416	282	350	420
Non-casein-N (g/kg total N)	193	186	206	190	193	204

DM, dry matter.

feed:gain ratio (g feed DM/g live-weight gain) but not live-weight gain was slightly improved by increasing the fat content from 280 to 420 g/kg diet (Cunningham & Brisson, 1955). Eusebio, Hays, Speer & McCall (1965) also found some improvement in the feed:gain ratio but a decreased live-weight gain when the fat level in the diet was increased from 200 to 380 g/kg.

EXPERIMENTAL

Diets and method of feeding

Six diets were prepared by mixing soya-bean oil or beef tallow, without an emulsifier, with portions of the same batch of skim milk. The mixtures were spray-dried by a mild heat process, to prevent denaturation of the whey proteins, after the addition of butylated hydroxytoluene as an antioxidant (14 mg/kg dried powder). Liquid diets containing 200 g total solids/l were prepared from these powders, supplemented with a mixture of fat-soluble vitamins, and fed at a scale based on live weight as previously described (Braude & Newport, 1973). The composition of the diets is given in Table 1. BL, BM and BH are diets with beef tallow at the low, medium and high levels respectively, and SL, SM and SH are diets with soya-bean oil at the low, medium and high levels respectively.

Experimental design and routine

Litter-mate, 2-d-old pigs were allocated to the six diets on the basis of live-weight and sex. Four pigs on each diet were housed in separate rearing rooms. This procedure was repeated three times, i.e. twelve pigs were given each diet.

Nitrogen retention

Urine was collected daily, with 25 ml glacial acetic acid added to the collecting bottle as a preservative. Samples were bulked over 4 d periods. Preliminary findings indicated that the amount of faecal N was so small that its determination was unnecessary. For the apparent digestibility studies, total collections of faeces were made over periods of 4 d.

Procedure at slaughter

At 28 d of age the pigs were killed 1 h after a feed by an intracardiac injection of sodium pentobarbitone. Only pigs that were healthy and that were consuming all of their meals within 5 min were killed. The alimentary tract was removed and the carcass stored at −20°. Samples of carcass were prepared for chemical analysis as described by Florence & Mitchell (1972).

Analytical methods

The methods described by Braude *et al.* (1970) were used to determine DM and total N, and that of Rowland (1938) to determine non-casein-N. Ash, total lipid, total fatty acids and fatty acid composition were determined as described by Braude & Newport (1973).

RESULTS

Live-weight gain and feed:gain ratio of the pigs

During the first week of life, increasing the proportion of either fat source reduced the growth rate, with a poorer feed:gain ratio for the diets BH and SH containing 400 g fat and 600 g skim milk/kg diet (Table 2).

The live-weight gain of the pigs, between 2 and 28 d of age, was not improved by increasing the proportion of fat in the diet at the expense of skim milk. Indeed, increasing the proportion of beef tallow in the diet slightly reduced the live-weight gain, but up to 400 g soya-bean oil/kg diet could be included without affecting the growth rate. The feed:gain ratio was unaffected by any of the diets. The diet did not appear to be associated with the deaths of three pigs, as indicated by post-mortem examination. Two pigs had been given diet BL, and one pig diet SH.

N retention

The N retention (g/d per kg live weight) is given below. The contamination of urine by diet, and in a few instances by scour, prevented the estimation of N retention in some of the pigs. The results, given as mean values with their standard errors for between two and seven determinations/treatment, were:

Diet (for details, see Table 1)	BL	BM	BH	SL	SM	SH
No. of determinations	2	5	3	5	7	6
N retention	1·80	1·91 ± 0·10	1·76 ± 0·03	1·80 ± 0·12	1·93 ± 0·05	1·76 ± 0·03

In general, the N retention differed little between the diets, but slightly higher values were obtained for the diets containing 335 g fat and 665 g skim milk/kg diet (BM and SM).

Table 2. *Live-weight gain (g/d) and feed:gain ratio (g feed dry matter/g live-weight gain) of pigs, between 2 and 7, and 2 and 28 d of age, given diets containing different proportions of skim milk and fat (either beef tallow or soya-bean oil)*

(Mean values for twelve pigs (mean initial body-wt 1·60 kg)/treatment; two pigs given BL, and one given SH died; missing values were calculated)

	Age (d)	Diet						SE of mean	Statistical significance of differences between:	
		BL	BM	BH	SL	SM	SH		Source of fat	Levels of fat and protein
Live-wt gain	2–7	162	161	122	167	159	144	6·5	*	*
Feed:gain ratio		0·67	0·70	0·86	0·69	0·68	0·75	0·028	NS	*
Live-wt gain	2–28	341	323	311	342	335	336	8·0	*	NS
Feed:gain ratio		0·82	0·83	0·81	0·80	0·82	0·81	0·011	NS	NS

There were no statistically significant ($P > 0·05$) interactions between litters, source of fat or levels of fat and protein.

BL, BM, BH, diets supplemented with beef tallow at low, medium and high levels respectively; SL, SM, SH, diets supplemented with soya-bean oil at low, medium and high levels respectively (for details of diets, see Table 1); NS, not significant.

* $P < 0·05$.

Table 3. *Carcass weight, carcass dry matter* (DM) *content, and crude protein (nitrogen* $\times 6·25$*), lipid and ash content of the carcass* DM *of 28-d-old pigs given diets containing different proportions of skim milk and fat (either beef tallow or soya-bean oil)*

(Mean values for eight pigs/treatment)

	Diet						SE of mean	Statistical significance of differences between:	
	BL	BM	BH	SL	SM	SH		Source of fat	Levels of fat and protein
Carcass weight (kg)	9·58	9·23	8·84	9·76	9·86	9·87	0·337	**	*
Carcass DM (g/kg)	348	364	381	367	384	383	4·4	**	***
Crude protein (g/kg DM)	392	378	343	376	352	336	8·5	**	***
Lipid (g/kg DM)	457	479	526	485	503	535	13·8	NS	***
Ash (g/kg DM)	83·9	76·3	69·7	90·0	80·6	74·1	1·26	**	***

There were no statistically significant ($P > 0·05$) interactions between litters, source of fat or levels of fat and protein.

BL, BM, BH, diets supplemented with beef tallow at low, medium and high levels respectively; SL, SM, SH, diets supplemented with soya-bean oil at low, medium and high levels respectively (for details of diets, see Table 1): NS, not significant.

* $P < 0·05$; ** $P < 0·01$; *** $P < 0·001$.

Table 4. *Apparent digestibilities of dry matter, total lipid, total fatty acids and of myristic, palmitic, stearic, oleic and linoleic acids in 21–28-d-old pigs given diets containing different proportions of skim milk and fat (either as beef tallow or soya-bean oil)*

(Mean values with their standard errors)

Diet ...	BL		BH		SL		SH	
No. of pigs ...	4		7		7		3	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Dry matter	0·970	0·0061	0·976	0·0025	0·995	0·0005	0·995	0·0003
Total lipid	0·971	0·0025	0·981	0·0028	0·992	0·0021	0·993	0·0005
Total fatty acids	0·975	0·0039	0·984	0·0024	0·996	0·0012	0·995	0·0001
Myristic acid	0·987	0·0031	0·996	0·0008	—*		—*	
Palmitic acid	0·966	0·0062	0·982	0·0017	0·992	0·0021	0·992	0·0013
Stearic acid	0·962	0·0059	0·973	0·0038	0·973	0·0061	0·968	0·0030
Oleic acid	0·992	0·0017	0·995	0·0005	0·998	0·0008	0·999	0·0058
Linoleic acid	—*		—*		1·000		1·000	

BL, BH, diets supplemented with beef tallow at low and high levels respectively; SL, SH, diets supplemented with soya-bean oil at low and high levels respectively (for details of diets, see Table 1).
* There was no myristic acid in diets SL or SH, or linoleic acid in diets BL or BH.

Chemical analysis of the carcass

Eight pigs/treatment were analysed and the results are given in Table 3. The proportion of lipid in the carcass was higher on the soya-bean-oil than the beef-tallow diets, although the difference was not significant ($P > 0{\cdot}05$), and was increased when the proportion of either fat source in the diet was increased. Increasing the proportion of fat also tended to increase the DM content of the carcass, and there were decreased ash and crude protein ($N \times 6{\cdot}25$) contents. The carcasses of pigs given the soya-bean-oil diets had a higher ash content than those receiving the beef-tallow diets.

Apparent digestibilities, and fatty acid content and composition of digesta

The apparent digestibilities of DM, total lipid, total fatty acids and of myristic, palmitic, stearic, oleic and linoleic acids are given in Table 4. The apparent digestibilities of all the components measured were greater than 0·96. In general, digestibilities were higher with the soya-bean-oil diet.

We confirmed our previous finding that the fatty acid content of the digesta in the small intestine was greater when beef-tallow diets were fed compared with diets containing soya-bean oil. The composition of the digesta was also similar to that reported previously (Braude & Newport, 1973).

DISCUSSION

There was no improvement in live-weight gain, feed:gain ratio or N retention in response to an increase in the energy content of the diet by increasing the proportion of fat, and furthermore a slightly decreasing effect on live-weight gain was found with the beef-tallow diet. The absence of response to the increased dietary energy levels

may have been due to the accompanying decrease in protein content of the high-fat diets.

Increased fat and decreased protein contents were found in the carcass when the proportion of fat in the diet was increased. Similar effects have been reported by Schneider & Sarett (1966) and Filer, Owen & Fomon (1966). Our results indicate that an energy:protein ratio greater than that in diets containing 280 g fat and 260 g protein/kg DM has an unfavourable influence on the body composition of the baby pig.

The apparent digestibilities indicated that there was complete, or almost complete, digestion of oleic and linoleic acids compared with the slightly less complete digestion of palmitic and stearic acids. The presence of eicosanoic, docosanoic and tetracosanoic acids in the faecal lipids must be derived from endogenous sources, probably bacterial, as these fatty acids were absent from the diet.

In conclusion, it seems unlikely that the utilization by the baby pig of the diet containing 270 g fat and 730 g skim milk/kg diet can be improved by further replacement of the skim milk by fat. Soya-bean oil was slightly better than beef tallow, confirming the findings of a previous experiment (Braude & Newport, 1973).

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REFERENCES

Braude, R., Coates, M. E., Henry, K. M., Kon, S. K., Rowland, S. J., Thompson, S. Y. & Walker, D. M. (1947). *Br. J. Nutr.* **1**, 64.
Braude, R., Mitchell, K. G., Newport, M. J. & Porter, J. W. G. (1970). *Br. J. Nutr.* **24**, 501.
Braude, R. & Newport, M. J. (1973). *Br. J. Nutr.* **29**, 447.
Cunningham, H. M. & Brisson, G. J. (1955). *Can. J. agric. Sci.* **35**, 371.
Eusebio, J. A., Hays, V. W., Speer, V. C. & McCall, J. T. (1965). *J. Anim. Sci.* **24**, 1001.
Filer, L. J. Jr, Owen, G. M. & Fomon, S. J. (1966). In *Swine in Biomedical Research*, p. 141 [L. K. Bustad and R. O. McClellan, editors]. Richland, Washington: Battelle Memorial Institute.
Florence, E. & Mitchell, K. G. (1972). *Proc. Br. Soc. Anim. Prod.* **1**, 101.
Frobish, L. T., Hays, V. W., Speer, V. C. & Ewan, R. C. (1967). *J. Anim. Sci.* **26**, 1478.
Rowland, S. J. (1938). *J. Dairy Res.* **9**, 42.
Schneider, D. L. & Sarett, H. P. (1966). *J. Nutr.* **89**, 158.

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