Artificial rearing of pigs

3.* The effect of heat treatment on the nutritive value of spray-dried whole-milk powder for the baby pig

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(*Received* 31 *March* 1970—*Accepted* 11 *August* 1970)

1. Baby pigs were removed from the sow 36–48 h after birth and reared on a diet of reconstituted whole-milk powder until 28 d of age. The whole milk was either mildly or severely heated before spray-drying; the severe heating completely denatured the whey proteins.

2. When the two milks were given at a high level of intake, either at hourly intervals or twice daily, severe scouring and some deaths occurred, the incidence being higher among pigs receiving the severely heated milk. The severe heat treatment also reduced the nutritive value of the milk powder as measured by the performance of the pigs during the 1st week of life. However, no difference in the nutritive value of the two milks was apparent for the surviving pigs over the whole experimental period.

3. There were no deaths when the two milks were given at a moderate level of intake and at hourly intervals. The effect of heat treatment on performance was similar to that at the high level of intake.

4. The apparent digestibility of the nitrogen in the diet was similar for both milks. However, balance trials could not be carried out when scouring occurred, when differences between the milks were most likely to be apparent. The N retention was similar with both milks at 7 d of age, although retention was higher when the severely heated milk was given to pigs between 14 and 21 d of age.

5. The digestion of the two milks was studied in 28-d-old pigs. The ability of the severely heated milk to clot in the stomach was greatly reduced compared with that of the mildly heated milk, but the performance of the pigs was unaffected. No other differences in the digestion of the milks were found. The ability of the diet to clot in the stomach appeared to be unimportant at this age.

6. It is possible that a reduction in the clotting ability of the severely heated milk was responsible for the decreased efficiency of digestion during the 1st week of life.

When liquid milk is spray-dried after prolonged heating at a high temperature, either partial or complete denaturation of the whey proteins occurs, depending on the severity of heating. Upon reconstitution and acidification of a milk powder prepared in this way, the denatured whey proteins will precipitate with casein, and the milk will be found to have a low content of the non-casein nitrogen (NCN) fraction when assayed by the procedure of Rowland (1938). The amount of the NCN fraction relative to total N gives a measure of the extent of denaturation of the whey proteins, and thus of the severity of the heating. Milk subjected to severe heating before spray-drying is detrimental to the newborn calf. Shillam, Roy & Ingram (1962) compared the performance of calves given milk powders prepared by severe or mild heating before spray-drying, and having NCN contents of 15 % and 22 %, respectively, of the total N. There was a high incidence of 'infection' in the calf-house during the experiments and the mortality rate was greater among calves receiving the milk subjected to severe heating. The weight gain of surviving calves was also poorer when

* Paper no. 2: *Br. J. Nutr.* (1970), **24**, 827.

given this milk. When these two milks were given in a subsequent experiment carried out under conditions of low 'infection' in the calf-house, no deaths occurred, but the weight gain of the calves given the severely heated milk was again poorer (Shillam & Roy, 1963*a*). The apparent digestibility of N was greater with the milk which had been only mildly heated, although the biological value of the two milks did not differ (Shillam & Roy, 1963*a*). This reduced digestibility contributed to the poorer nutritive value of the severely heated milk for the calf, and it is also likely that impairment of the clotting properties of the milk was a further contributory factor (Shillam & Roy, 1963*b*).

When baby pigs were artificially reared from 2 d of age and given a whole-milk diet at a high level of intake, severe scouring often occurred, resulting in a high mortality rate. However, in some experiments the pigs did not scour and grew well (Braude, Mitchell, Newport & Porter, 1970; and unpublished results). The spray-dried whole-milk powder used contained a large proportion of denatured whey protein, indicating that it had been severely heated before drying and this may have been responsible for the poor results in some of these experiments. Also, post-mortem examinations indicated that the level of feeding may have exceeded the digestive capacity of the baby pigs. Therefore, experiments have been carried out to investigate the effect of heat treatment on the nutritive value of spray-dried whole-milk powder for the baby pig.

In all our previous experiments on artificial rearing of pigs, the pigs in each isolated rearing-room were allocated to the same treatment and therefore room and treatment effects were confounded. Although all the rooms are theoretically identical, it is possible that infections may not occur to the same extent in all rooms. The second experiment now described was designed to test this hypothesis.

EXPERIMENTAL

Diets

Two spray-dried whole-milk powders were prepared from the same bulk of liquid milk by different heat treatments. In the first process, milk was heated to 88° and held at this temperature for 30 min before drying. The whey proteins in this powder (SH) were largely denatured and the NCN content was 10·3 % of the total N. In the second process, the milk was heated to 66° and passed immediately to the drier. Little denaturation of the whey proteins occurred in this powder (MH), and the NCN content was 20·7 % of the total N.

The preparation of the diets from these milk powders was as described previously (Braude, Mitchell *et al.* 1970). The milk was reconstituted to 20 % content of total solids in the first experiment, and to 12·5 % content in the second experiment.

Experimental design

The procedure described by Braude, Mitchell *et al.* (1970) was followed, using pigs 36–48 h old. In all experiments an initial environmental temperature of 30° was maintained and a gradual reduction made to 20° during the initial 14 d of the experiment, which lasted for 26 d. Litter-mate pigs were allocated at random to four treatments. Owing to limitation of space, four pigs per treatment forming a replicate were on experiment at any one time. There were three such replicates in the first experiment and two in the second.

Expt 1. The pigs were fed according to live weight and at a high level of intake, scale C, as defined by Braude, Mitchell *et al.* (1970). The two milks were given either at hourly intervals or twice daily.

Expt 2. All pigs were given milk at a moderate level, scale B, as defined by Braude, Mitchell *et al.* (1970) at hourly intervals. Within each isolated rearing-room, either all four pigs received the same milk, or two pigs received one milk and two the other. These rooms will be referred to as 'single' and 'mixed' treatment rooms.

Measurement of N retention

N retention was measured over two periods, each of 6 d. The procedure described by Braude, Mitchell *et al.* (1970) was followed for the collection of excreta.

Digestion studies

The procedure for slaughtering the pigs and removal of organs and digesta was as described by Braude, Mitchell *et al.* (1970). The extent of digestion of the milk protein was assessed after slaughter of the pigs at 28 d of age, at the end of the growth experiments. In Expt 1, in which the diet was given at a high level of intake, only pigs from the first two replicates were slaughtered. Pigs fed twice daily were allowed to consume their morning meal (one-third of their daily ration) and killed 1 h later. Pigs fed at hourly intervals were also killed 1 h after a meal. In Expt 2, pigs were fed at hourly intervals and slaughtered at 5, 10, 20 or 60 min after a feed.

Analytical methods

Dry matter, total and non-protein N were estimated by the methods described by Braude, Mitchell *et al.* (1970), and proteolytic enzyme activity as described by Braude, Newport & Porter (1970). The method of Rowland (1938) was followed for the estimation of NCN.

RESULTS

Mortality

In Expt 1, when the milk was given at a high level of intake, the mortality rate was high, and greatest among the pigs receiving milk SH at hourly intervals (Table 1). Post-mortem examination of pigs that died revealed large amounts of digesta in the stomach in several instances and showed that all pigs had a coliform infection in the intestines and had scoured severely. No pigs died in Expt 2, in which the milks were given at hourly intervals at a moderate level of intake. In both experiments the incidence of scouring was greater among pigs given milk SH.

Growth

Separate analyses of the results were carried out for the periods from 2–7 and 2–28 d of age and are given in Tables 2 and 3. The results for the period 2–7 d of age were unaffected by the exclusion of the results for pigs that died in the later part of the experiment and, in order to facilitate comparison between the two periods, the results in the tables refer to pigs surviving for the whole experimental period.

When the milk was given at a high level of intake, the performance of the surviving pigs over the whole period was unaffected by the heat treatment of the milk powder. The performance over the first 7 d was better when milk MH was given, although the differences in daily weight gain did not attain significance at the 5 % level. The very high feed conversion ratio on milk SH was due to scouring which affected the daily gain.

Similar results were obtained in Expt 2 when the two milks were given at the moderate level of intake: the performance of the pigs over the whole experimental period was unaffected by the heat treatment of the milk powder, but during the initial 7 d the performance was better when milk MH was given. The performance of pigs kept in 'mixed' treatment rooms was little different from that of pigs kept in 'single' treatment rooms.

Table 1. *Expt 1. Death rate of baby pigs fed at a high level of intake, either hourly or twice daily, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating*

(Initially there were four pigs in each replicate)

	SH		MH	
	Hourly	Twice daily	Hourly	Twice daily
Replicate 1	0	0	0	1
2	3	2	2	0
3	3	3	1	0
Total	6	5	3	1

N retention

Studies on N retention could be carried out only with pigs producing normal faeces, as the rearing cages did not permit quantitative collection of excreta when pigs were scouring; this restricted the number of balance studies that could be made. However, the extent of scouring, although preventing quantitative collection of excreta, did not appear in general to be sufficiently severe to impair growth rate. The results in Table 4 show that milk SH had no adverse effect on N retention in healthy pigs. On the contrary, pigs between 13 and 19 d of age retained a significantly greater amount of N from this milk. The apparent digestibility of N for the baby pig was always high (98–99 %) and was unaffected either by diet or age.

Clotting and digestion of the milk in the stomach

The amount and composition of the digesta in the stomach when the milks were given at a high level of intake are shown in Table 5.

There was a considerable difference in the physical appearance of the stomach clot formed from the two milks; a fairly hard cheese-like clot was formed from milk MH and could be seen to contain distinct lumps of varying sizes, whereas milk SH formed no clearly defined clot, and was precipitated in the form of a fine flocculent mass.

Table 2. *Expt 1. Performance of baby pigs fed at a high level of intake, either hourly or twice daily, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating*

(Initially there were twelve pigs on each treatment)

	Age (d)	SH Hourly	SH Twice daily	MH Hourly	MH Twice daily	SEM† (18 df)	Significance of differences due to: Litter	Frequency of feeding	Milk
No. of pigs ...		6	7	9	11				
Live-weight gain (g/d)	2–7‡	118	136	166	152	23·0	**	NS	NS
	2–28	320	290	334	302	16·1	NS	*	NS
Feed conversion ratio (g milk dry matter/g live-weight gain)	2–7‡	2·54	2·10	0·89	1·38	0·68	*	NS	*
	2–28	0·91	0·97	0·90	1·02	0·05	NS	*	NS

NS, not significant ($P > 0·05$); * $P < 0·05$; ** $P < 0·01$.

† Calculated from the harmonic mean.

‡ Results for pigs that survived for the whole experimental period (see p. 115).

Table 3. *Expt 2. Performance of baby pigs fed at a moderate level of intake, at hourly intervals, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating, and the effect of 'single' and 'mixed' treatment rooms*†

	Age (d)	SH 'Single'	MH 'Single'	SH 'Mixed'	MH 'Mixed'	SEM and differences significant at the 5% level		Significance of differences due to: Litter	Milk	'Single'/'mixed' treatment rooms
Treatment no. ...		1	2	3	4					
No. of pigs/treatment ...		8	8	8	8					
Live-weight gain (g/d)	2–7	95	125	93	111	8·5	2 > 1, 3	***	**	NS
	2–28	259	251	246	256	8·0	NS	NS	NS	NS
Feed conversion ratio (g milk dry matter/g live-weight gain)	2–7	1·09	0·98	1·31	1·20	0·07	3 > 1, 2; 4 > 2	***	NS	**
	2–28	0·90	0·89	0·93	0·90	0·02	NS	*	NS	NS

NS, not significant ($P > 0·05$); * $P < 0·05$; ** $P < 0·01$; *** $P < 0·001$.

† 'Single', pigs in each room given only one milk; 'mixed', equal number of pigs in each room given either milk SH or MH.

Table 4. *Expt* 1. *Nitrogen retention (g/d per kg live weight) of baby pigs fed at a high level of intake, either hourly or twice daily, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating*

	SH		MH			Significance of differences due to:		
	Hourly	Twice daily	Hourly	Twice daily	SEM*	Litter	Frequency of feeding	Milk
Age (d)								
3–9								
No. of pigs	3	3	3	3				
N retention	2·73	2·74	2·77	2·74	0·13 (7 df)	NS	NS	NS
13–19								
No. of pigs	5	5	4	4				
N retention	1·88	2·04	1·50	1·83	0·12 (12 df)	NS	NS	$0·01 < P < 0·05$

NS, not significant. * Calculated from the harmonic mean.

Table 5. *Expt* 1. *Amount and composition of digesta in the stomachs of 28-d-old pigs fed at a high level of intake, either hourly or twice daily, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating*

	SH		MH		SEM* and differences significant at the 5% level	
	Hourly	Twice daily	Hourly	Twice daily		
Treatment no. ...	1	2	3	4		
No. of pigs ...	5	6	6	7		
Stomach clot						
Dry matter (g)	10·3	38·0	26·7	51·3	8·7	2, 4 > 1
N (mg)	450	2180	1419	2767	517	2, 4 > 1
Stomach whey fraction						
Dry matter (g)	1·69	5·44	0·47	1·95	1·4	NS
N (mg)	83	148	27	60	15	2 > 1, 3, 4; 1 > 3
Whey volume (ml)	28·3	57·8	6·7	20·5	16·0	2 > 3
N (mg/ml)	2·93	2·56	4·03	2·93	0·44	3 > 2
Non-protein N (mg/ml)	1·49	1·07	1·78	1·77	0·31	NS
Dry matter (mg/ml)	59·7	94·1	70·1	95·1	10·2	2, 4 > 1
Non-protein N as % total soluble N	51	42	44	60	7	NS
pH (mixed contents)	2·9	5·0	4·2	4·8	0·5	2, 4 > 1
Ratio, clot: whey dry matter	6·1	7·0	56·8	26·3	6·3	3 > 4 > 1, 2
Volume of final feed (ml)	92	615	95	690		

NS, not significant. * Calculated from the harmonic mean.

Table 6. *Expt 2. Amount and composition of digesta in the stomachs of 28-d-old pigs fed at a moderate level of intake, at hourly intervals, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating; pigs were slaughtered at different times after a meal*

	SH				MH						Significance of differences due to:			
Time after feeding (min)...	5	10	20	60	5	10	20	60	SE of difference	df	Time interval	Litter	Milk	Litter × milk
No. of pigs ...	4	4	4	3	3	4	4	4						
Live weight (kg)	8·6	8·7	8·6	8·7	8·6	8·8	8·7	8·7	1·66	22	—	—	—	—
Clotted digesta														
Dry matter (g)	10·14	11·70	8·96	8·61	17·08	21·47	18·36	12·07	2·57	19	*	**	***	***
N (mg)	440	514	383	412	728	1056	820	624	124	19	*	***	***	**
Soluble digesta														
Volume (ml)	76	50	53	18·4	56	59	31	6·4	11·7	22	***	NS	NS	NS
Dry matter (g)	4·93	3·38	2·94	0·88	3·85	3·84	1·94	0·35	0·57	22	***	NS	NS	NS
N (mg)	169	116	99	49	155	151	89	20	27	22	***	*	NS	NS
Non-protein N (as % total soluble N)	25	26	32	41	19	25	21	38	3	21	***	NS	**	NS
pH of mixed digesta	5·1	5·0	4·4	2·9	5·1	4·7	4·6	3·8	0·3	22	***	NS	NS	NS

NS, not significant ($P > 0·05$); * $P < 0·05$; ** $P < 0·01$; *** $P < 0·001$. SE of differences calculated from the harmonic means.
All pigs consumed 120 ml milk in the feed before slaughter.

The amount of digesta in the stomach clot was greater in pigs given milk MH, the effect being more marked when the milk was given at hourly intervals. The ratio of dry matter in the clot to that in the whey was also greater for this milk, reflecting the differences in the physical nature of the two types of clot.

The pH of the digesta was low when milk SH was given at hourly intervals. The buffering action of the milk on stomach pH was reduced under these conditions as a smaller quantity of digesta was retained in the stomach as a result of the poorer clotting properties of this milk.

The results of Expt 2 are shown in Table 6. The types of clot formed in the stomach from the two milks were similar to those found in Expt 1. In Expt 2 emptying of the clotted digesta from the stomach did not commence immediately after ingestion of the milk. The period of time before stomach emptying commenced was longer (20 min) with milk MH than with milk SH (10 min). The amount of soluble digesta rapidly declined after ingestion of the milk. The ratio of non-protein N to total soluble N increased with time after the meal and was slightly higher at all times after the meal when milk SH was given. The pH of the mixed digesta from milk SH ultimately attained a lower value than when milk MH was given.

Table 7. *Expt 1. Amount and composition of digesta in the small intestine of 28-d-old pigs fed at a high level of intake, either hourly or twice daily, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating*

	SH		MH		
	Hourly	Twice daily	Hourly	Twice daily	SEM*
No. of pigs ...	4	5	5	6	
Insoluble digesta					
Dry matter (g)	2·64	1·92	2·52	3·06	0·54
N (mg)	111	37	122	66	21·6
Soluble digesta					
Dry matter (g)	7·32	8·52	6·36	10·50	1·80
N (mg)	750	444	654	696	132

* Calculated from the harmonic mean.
Differences between segments, milks or frequency of feeding were not significant ($P > 0{\cdot}05$).

Amounts of digesta in the small intestine

A study of the digesta in the small intestine was made only in Expt 1. The amount and composition of the digesta in the small intestine are given in Table 7.

At 28 d of age, it would appear that neither the heat treatment of the milk nor the frequency of feeding had an appreciable effect on the amount and composition of the digesta in the small intestine. However, the amount of insoluble N did show some decrease with the less frequent feeding.

Proteolytic enzyme activity

The proteolytic enzyme activity in the stomach wall and pancreas was found to be unaffected either by the heat treatment of the milk powder, at either level of intake, or by frequency of feeding. The results are given in Tables 8 and 9. At the high level of intake, the proteolytic enzyme activity was greater in the stomach digesta with milk SH, although the difference was not significant ($P > 0.05$). There were no differences attributable to diet at a moderate level of intake in the enzyme activity of the digesta or stomach wall. The proteolytic enzyme activity of the pancreas was unaffected by either the heat treatment of the milk powder or frequency of feeding.

Table 8. *Expt 1. Proteolytic enzyme activity in the stomach wall, stomach digesta and pancreas of 28-d-old pigs fed at a high level of intake, either hourly or twice daily, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating*

	SH		MH		
	Hourly	Twice daily	Hourly	Twice daily	
Treatment no. ...	1	2	3	4	SEM*
No. of pigs ...	5	6	6	7	
Stomach wall: wet tissue (mg/g)	3.2	2.8	3.2	3.0	0.3
total (mg)	193	169	185	202	21
Stomach clot: wet digesta (μg/g)	245	129	148	94	45
total (mg)	15.1	19.6	9.4	14.2	4.5
Whey fraction: μg/ml	11	31	23	36	7
total (mg)	0.3	1.2	0.1	0.7	0.3
Total contents (mg)	15.4	20.8	9.5	14.9	4.6
Pancreas: wet tissue (mg/g)	70	63	62	72	3.0
total (mg)	1210	1014	863	1006	75

* Calculated from the harmonic mean. The treatment means were not significantly different ($P > 0.05$) except in the total whey fraction where the mean value for milk SH given twice daily was greater ($P < 0.05$) than when either milk was fed at hourly intervals.

DISCUSSION

Growth experiments

The effect of heat treatment of the milk powder on performance was confined to the initial stages of growth. The performance between 2 and 7 d of age was better with milk MH. During this period, some deaths were recorded in the experiment with the high level of intake; pigs that died later in the experiment were scouring and often had distended abdomens. Braude, Mitchell *et al.* (1970) have shown that the baby pig may have difficulty in efficiently digesting a whole-milk diet given at a high level of intake. It was not surprising, therefore, that the difference in nutritive value of the two milks was markedly greater in the first than in the second experiment, in which a moderate level of feeding was used.

In both experiments, the performance from 2 to 28 d of the surviving pigs was unaffected by the heat treatment of the milk powder. In this respect, these results differ from those of Roy and co-workers (Shillam *et al.* (1962); Shillam & Roy (1963*a*, *b*)), who found that the growth rate of surviving calves was lower when given a milk prepared from severely heated skim-milk powder with added margarine than when a mildly heated milk was given.

The comparison between 'single' and 'mixed' treatment rooms showed little

Table 9. *Expt 2. Proteolytic enzyme activity in the stomach wall and stomach digesta of 28-d-old pigs fed at a moderate level of intake, at hourly intervals, on whole milk reconstituted from a powder that had been spray-dried after severe (SH) or mild (MH) heating; pigs were slaughtered at different times after a meal*

	SH				MH				SE† of difference (22 df)	Significance of differences due to:		
Time after feeding (min) ...	5	10	20	60	5	10	20	60		Litter	Milk	Time after feeding
No. of pigs ...	4	4	4	3	3	4	4	4				
Stomach wall:												
Wet tissue (mg/g)	3·28	2·57	3·17	2·07	2·83	3·05	2·84	2·47	0·41	***	NS	NS
Total (mg)	163	117	157	96	130	145	140	107	23	***	NS	NS
Stomach digesta:												
Wet wt (μg/g)	162	166	203	192	152	189	198	233	30	***	NS	*
Total (mg)	8·9	10·0	8·4	8·0	10·1	13·9	11·9	11·0	2·5	***	NS	NS

NS, not significant ($P > 0·05$); *$P < 0·05$; ** $P < 0·01$; *** $P < 0·001$.

† Calculated from the harmonic mean.

difference between the two procedures, and the assumption that an identical environment exists in all rearing rooms seems valid.

Both live-weight gain and feed conversion ratios were improved by feeding at hourly intervals compared with twice daily. Previously, Braude, Mitchell *et al.* (1970) found that the more frequent feeding improved only the feed conversion.

Digestion studies

The major difference in digestion of the two milks arose from the differences in their ability to clot in the stomach. A hard cheese-like clot was formed from milk MH, but milk SH formed only a flocculent precipitate. Similar results were obtained with the two milks in the abomasum of the calf (Shillam & Roy, 1963*b*). The results of the experiments reported here showed that, in pigs fed at hourly intervals, stomach emptying proceeded more rapidly when milk SH was given, as would be expected from the reduced clotting ability of this milk. Thus a considerable amount of undigested material passed into the small intestine when milk SH was given.

The digestion studies were made with 28-d-old pigs which were able to utilize both milks with equal efficiency, indicating that the difference in clotting ability was of minor importance at this age. However, during the first 7 d of age, this difference would probably be more marked as the gastric secretory system is still poorly developed; the amount of proteinase in the tissue of the stomach wall is much smaller than at 28 d of age (Braude, Dollar, Mitchell, Porter & Walker, 1958; Hartman, Hays, Baker, Neagle & Catron, 1961) and secretion of hydrochloric acid does not commence until 20–30 d of age (Kvasnitskii & Bakeeva, 1940). Cranwell, Noakes & Hill (1968) reported that secretion of hydrochloric acid commenced at 30 d of age in pigs reared in a conventional environment, but commenced within 7 d of birth in pigs reared in a clean environment. Similar amounts of proteolytic enzyme were found in the stomach wall and digesta with both milks, although, in general, lower stomach pH values were found, together with more non-protein N relative to total soluble N, when milk SH was given at hourly intervals. Therefore, it would appear that more proteolysis occurred with milk SH, but that the poorer clotting and increased rate of stomach emptying of this milk reduced the time available for proteolysis in the stomach. When the pigs were fed twice daily, the amount of non-protein N relative to total N and the pH of the stomach digesta were greater when milk MH was given although the differences were not significant ($P > 0.05$). Tagari & Roy (1969) also found similar differences due to heat treatment of the milk in the pyloric outflow from calves fitted with a duodenal re-entrant cannula.

The amount of digesta in the small intestine was unaffected by the heat treatment of the milk powder, and since a high level of proteolytic enzyme activity was found in the pancreas it seems likely that the digestion of both milks was efficiently completed in this region of the alimentary tract.

The total proteolytic enzyme activity of the pancreas also increases with age (Braude *et al.* 1958), and in the first few days after birth may have been insufficient to digest protein flowing rapidly into the small intestine when milk SH was given.

The effect of frequency of feeding on digestion of the milk protein was similar to that found previously (Braude, Mitchell *et al.* 1970). In general, differences in digestion due to the heat treatment of the milk powder were similar when the milk was given either at hourly intervals or twice daily.

General

It was found beneficial during the first 7 d of life to give the baby pig milk reconstituted from a spray-dried powder prepared by a mild heating procedure. It is known that enzyme and acid secretions are low at this age and therefore the clotting of milk in the stomach will be less efficient than in older pigs. A milk of poor clotting ability given at a high level of intake may well induce a rate of stomach emptying into the small intestine too great for digestion to be efficiently completed, and undigested material in the small intestine would predispose the baby pig to infection from strains of pathogenic bacteria. It seems likely that the reduction in nutritive value of the severely heated milk for the baby pig was a result of impaired digestion caused by poor clotting in the stomach followed by too rapid passage into the small intestine. This condition was magnified at the high level of intake when some deaths occurred. In the 28-d-old pig, the digestive system had developed sufficiently to digest both milks equally efficiently, and differences in clotting of the milk in the stomach at this age appeared to be of minor importance.

A high level of feeding seemed to predispose the baby pig to 'infection' and possible death, the incidence of which was greater when milk SH was given. In this respect, a similar response was found with calves in that deaths occurred only under conditions of 'high' infection, and were more numerous among calves receiving the severely heated milk (Shillam *et al.* 1962; Shillam & Roy, 1963*a*). However, the live-weight gain of calves was reduced by the severely heated milk, but, when baby pigs were given similar milk, growth was depressed only during the first 7 d of life.

It is desirable to feed artificially reared pigs at a high level so as to utilize their growth potential, and therefore a powder prepared from milk that has been spray-dried after mild heat treatment and contains undenatured whey proteins should be used. As the milk powders were prepared after heat treatments designed either to denature the whey proteins completely or to leave them unaltered, it is not possible to predict from these experiments the severity of heat treatment and denaturation of whey protein permissible without a reduction in the nutritive value for the baby pig.

The authors thank R. T. Medley, J. G. Evans and A. R. G. Wright for technical assistance, and Miss H. R. Chapman and staff of the Experimental Dairy for the preparation of the diets. Thanks are also due to L. E. Pritchitt and Co. Ltd, London for the preparation of the spray-dried milk powders, and Mrs A. Gush, Veterinary Investigation Centre, MAFF, Coley Park, Reading who carried out the post-mortem investigations.

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Printed in Great Britain