The effect of frequency of feeding on the response by growing pigs to supplements of free lysine

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1. Six experiments, involving a total of 320 pigs, were conducted to examine the reponse of growing pigs to diets supplemented with free lysine when fed either once daily or in six equal portions at intervals of 3 h. The effect of dry or wet feeding on the response to free lysine was examined in Expt nos. 4 and 5. The assumption of linear lysine response over the range of lysine supplementation was examined in Expt no. 6.

2. A significant ($P < 0{\cdot}01$) interaction between lysine supplementation and frequency of feeding occurred for growth rate and food conversion ratio. Growth responses to the supplements of free lysine with once daily feeding were only 67 % of that achieved with frequent feeding.

3. Wet feeding had no effect on the growth responses to free lysine supplements.

4. The lysine response was linear over the range of lysine supplementation examined.

5. The implications of these results to the interpretation of experiments examining the lysine requirements of pigs are discussed.

Batterham (1974) reported that the utilization of free lysine by pigs fed once daily was only 43 % of that of pigs fed the same ration in six equal portions at three-hourly intervals. It was suggested that the lower response with once daily feeding was due to differential rates of absorption of the free lysine and the protein-bound amino acids. By frequent feeding, a more balanced supply of amino acids would arrive at the sites of absorption and metabolism, thereby resulting in more efficient utilization.

It is possible, however, that the efficiency of utilization of supplements of free lysine with once daily feeding may vary, depending on a number of factors, including the constituents of the basal diets and the period of time taken to digest the daily ration. Variation in the constituents of the basal diet could affect free lysine utilization because the actual absorption rates of protein-bound amino acids may vary depending on the source of protein, its extent of processing and the energy component of the diet (Gupta, Dakroury & Harper, 1958; Rogers, Chen, Peraino & Harper, 1960; Goldberg & Guggenheim, 1962; Buraczewski, Porter, Rolls & Zebrowska, 1971). Similarly the period of time taken for pigs to consume a ration given once daily may vary from 10–20 min when the ration is presented wet to 40–90 min when it is presented dry. This difference could affect the rate at which supplements of free lysine arrive at the sites of absorption and metabolism and thus affect its subsequent utilization.

In the work reported in this paper, six experiments were conducted to examine the response of pigs to supplements of free lysine with once daily compared to frequent feeding, and using a range of basal diets. In addition, the effect of wet and dry feeding on the response to free lysine was examined in Expt nos. 4 and 5. In Expt no. 6 the assumption of a linear lysine response was examined to determine if two points (as in Expt nos. 1–5) were adequate to describe the lysine response.

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EXPERIMENTAL

Diets were formulated from a range of cereals and protein concentrates to be deficient in lysine (Table 1) but to contain sufficient other amino acids (Table 2) to allow growth responses of 20–30% to the lysine supplements. In Expt nos. 1–5, the diets were supplemented with either 2 or 4 g L-lysine/kg. The level of 2 g L-lysine/kg diet was chosen to observe the response to lysine under the two feeding regimens in conditions in which the full response to the added lysine should be obtained. The level of 4 g L-lysine/kg diet was chosen to show that the diets supplemented with 2 g L-lysine/kg were in fact still lysine deficient. This treatment was restricted to the frequent feeding regimen only, because it was anticipated that the response to 4 g L-lysine/kg diet with this feeding regimen would be equal to or superior to that with once daily feeding. In Expt no. 6, the basal diet was supplemented with either 1,2,3 or 4 g L-lysine/kg to allow a response curve to lysine supplementation to be defined for both feeding regimens.

The once daily feeding was at 08.00 hours and the six feeds were at 05.00, 08.00, 11.00, 14.00, 17.00 and 20.00 hours respectively. The rations were presented dry in Expt nos. 1, 2 and 3, dry or wet (by addition of water (1:1, w/v)) in Expt nos. 4 and 5 and wet in Expt no. 6.

The dietary components were analysed for crude protein (nitrogen × 6·25) by macro-Kjeldahl technique using selenium as the catalyst. Total amino acids were determined after reflux hydrolysis under N_2 in 6 M-hydrochloric acid and separation of the amino acids by ion-exchange chromatography. The digestible energy (DE) content of the diets was calculated from literature values (National Academy of Sciences, 1969).

The dietary treatments were arranged in a randomized block design in all experiments. In Expt nos. 1–5 there were four castrate males and four females/treatment and in Expt no. 6, the number of animals was halved to enable the number of treatments to be doubled. In all experiments, Large White pigs were used and were selected on the basis of sex and 7-week weight. The pigs were penned individually and water was supplied by nipple drinkers. The pigs were trained to consume approximately 1000 g starter diet in less than 1 h and the dietary treatments were introduced when the pigs reached 20 kg live weight.

The diets were offered at a daily rate of 1000 g at 20 kg live weight, increasing by 100 g/2·5 kg weight gain. The pigs were weighed weekly and rations were adjusted. The pigs were slaughtered after reaching a minimum weight of 45 kg. The carcases were chilled overnight and cold carcase weight recorded. The ham was dissected and the lean content used as an indicator of carcase leanness. Pig response was assessed in terms of live-weight gain/d, food conversion ratio (kg food eaten/kg live-weight gain), dressing percentage (cold carcase weight expressed as a percentage of live weight) and lean content in the ham.

The results from each experiment were analysed individually. In addition, a combined analysis of the results from all experiments was undertaken. In the latter analysis, only the relevant 'treatment' results from Expt no. 6 were included.

RESULTS

The results of the combined analyses of the results from the six experiments are presented in Table 3. The individual treatment means for weight gain/d for the six experiments are presented in Table 4.

A significant interaction between lysine supplementation and frequency of feeding occurred for growth rate ($P < 0·01$) and food conversion ratio ($P < 0·05$). The difference in lysine response between single and frequent feeding was 28 g/d for live-weight gain and 0·10 for food conversion ratio expressed on a per 2 g L-lysine/kg diet basis.

Table 1. *Composition (g/kg) of the experimental diets given to pigs*

	Expt no.			
	1 and 4	2	3	5 and 6
Ingredients†				
Wheat (cultivar Robin)	890	—	—	—
Wheat (cultivar Eagle)	—	860	—	822
Sorghum (*Sorghum vulgare* Pers.)	—	—	720	—
Meat meal	100	—	—	—
Sunflower meal	—	100	—	100
Peanut meal	—	—	120	—
Linseed meal	—	—	120	—
Soya-bean meal	—	—	—	35
Bone flour	—	30	30	30
Minerals and vitamins‡	5	5	5	5
Starch§	5	5	5	8

† The crude protein (nitrogen × 6·25; g/kg) and moisture (g/kg) contents of the ingredients were respectively: 'Robin' wheat 127, 109; 'Eagle' wheat 160, 117; sorghum 90, 124; meat meal 504, 52; sunflower meal (prepress solvent) 372, 69; peanut meal (expeller) 486, 61; linseed (expeller) 366, 97; soya-bean meal (prepress solvent) 462, 128.

‡ Contributed (/kg diet): iron 60 mg, zinc 100 mg, manganese 30 mg, copper 5 mg, iodine 2 mg, selenium 0·15 mg, NaCl 2·5 g, retinol equivalent 960 μg, cholecalciferol 12 μg, α-tocopherol 10 mg, thiamin 1 mg, riboflavin 3 mg, nicotinic acid 12 mg, pantothenic acid 10 mg, pyridoxine 1·5 mg, cyanocobalamin 15 μg, pteroylmonoglutamic acid 2 mg, choline 500 mg, ascorbic acid 10 mg, biotin 0·1 mg. In Expt nos. 5 and 6 10 mg oxytetracycline hydrochloride.

§ The starch was replaced by L-lysine monohydrochloride, anhydrous, 98% feed-grade, containing 780 g L-lysine/kg and manufactured by Kyowa Hakko Kogyo Co. Ltd, Japan.

Table 2. *Chemical composition (g/kg) of the experimental diets† given to pigs*

	Expt no.			
	1 and 4	2	3	5 and 6
Crude protein (nitrogen × 6·25)	163	175	167	185
Essential amino acids				
Threonine	4·2	4·7	5·0	5·2
Valine	6·2	8·1	7·3	8·5
Methionine + cystine	4·4	6·4	4·3	6·6
Isoleucine	4·9	6·7	6·2	7·2
Leucine	10·4	12·0	14·9	12·8
Phenylalanine + tyrosine	10·3	13·1	13·3	14·1
Lysine	5·7	4·8	5·1	5·5
Histidine	3·5	4·3	4·4	4·6
Arginine	8·2	9·2	12·7	10·0
Digestible energy (estimated) (MJ/kg)	14·5	14·2	13·9	14·1

† For details, see Table 1.

In Expt nos. 4 and 5, for once daily feeding, the pigs ate the wet rations in 22 min (SEM 1·2) compared to 59 min (SEM 2·3) when dry. Wet feeding increased growth rate (26 g/d; $P < 0·05$) and decreased both the food conversion ratio (0·15; $P < 0·01$) and the dressing percentage (1·9%; $P < 0·01$). There were no interactions between lysine supplementation and wet or dry feeding except for lean in the ham, where the response to free lysine was greater with wet feeding (7%) than with dry feeding (1%).

In Expt no. 6, only the linear component of lysine response was significant ($P < 0·01$). It was the only component of the lysine response to vary significantly ($P < 0·01$) between the number of feeds/d.

Table 3. *Effect of frequency of feeding on the response by pigs to supplements of free lysine† during the 20–47 kg growth phase*

(Analysis of the results from six experiments involving sixty pigs/treatment. Lysine utilization with once daily feeding was 67 %. This was determined by expressing the response to free lysine with once daily feeding as a percentage of the response to free lysine with frequent feeding)

Frequency of feeding (*F*) (no. of feeds/d)	L-lysine (*L*) (g/kg)	Live-wt gain (g/d)	Food conversion ratio‡	Lean in ham (g/kg)	Dressing percentage§
1	0	435	3·09	601	73·8
1	2	491	2·75	630	73·6
6	0	446	3·01	591	72·9
6	2	530	2·57	635	73·3
6	4	553	2·45	651	73·2
SEM	—	5	0·02	3	0·2
Statistical significance of treatment:					
F		**	**	NS	**
L		**	**	**	NS
F×*L*		**	*	NS	NS
Wet and dry feeding (*W*/*D*)		*	**	NS	**
W/*D*×*F*		NS	NS	NS	NS
W/*D*×*L*		NS	NS	**	NS
W/*D*×*F*×*L*		NS	NS	NS	NS
Expt×*F*		*	**	NS	*
Expt×*L*		*	*	**	NS
Expt×*F*×*L*		NS	NS	NS	NS

NS, not significant ($P > 0{\cdot}05$).
* $P < 0{\cdot}05$, ** $P < 0{\cdot}01$.
† For details of diets and dietary regimens, see p. 266 and Tables 1 and 2.
‡ kg food eaten/kg live-weight gain.
§ Cold carcase weight expressed as a percentage of live weight.

DISCUSSION

The results confirm previous results (Batterham, 1974) that frequent feeding increases the utilization of free lysine, i.e. there is a significantly larger response to free lysine with frequent feeding than with once daily feeding. The estimate of 67% utilization (Table 3), based on experiments involving 320 pigs, can be taken as a more reliable estimate than that of 43% reported by Batterham (1974). The latter estimate was based on a single experiment and was within the range of individual estimates encountered in the current experiments. The variation in individual estimates for lysine utilization probably reflects the effect of 'within experiment' pig variation. Lysine utilization was determined by expressing the response to lysine with once daily feeding as a percentage of the response with frequent feeding. Such values are sensitive to small changes in pig response on any one treatment. As the response to lysine was linear over the range of supplementation examined in Expt no. 6, the design used in Expt nos. 1–5 was the most appropriate for assessing lysine utilization. This is because a linear response is best examined by positioning the treatments at each end of the range. It is evident that with the values for standard errors associated with growth experiments considerable replication is needed when assessing lysine utilization.

The utilization of lysine with once daily feeding did not appear to be effected by the food components examined in the current experiments. However due to the variation in individual estimates of lysine utilization the effect of any single dietary component would have to be substantial before it would have been detected. As there was no effect on lysine utilization of the period of time taken by pigs to consume the daily ration it is doubtful that small differences in absorption rates of protein bound amino acids would have had any effect. Wet

Table 4. *Live-wt gain (g/d) of pigs during the 20–47 kg growth phase when given diets† either wet or dry and supplemented with* L-*lysine hydrochloride*

(Results of six individual experiments)

Frequency of feeding (*F*) (no. of feeds/d)	L-lysine (*L*) (g/kg)	Expt no. ...	1	2	3	4		5		6
		Type of feeding ...	Dry	Dry	Dry	Dry	Wet	Dry	Wet	Wet
		No of pigs/treatment ...	8	8	8	8	8	8	8	4
1	0		469	379	400	449	461	443	443	450
	1									475
	2		556	480	454	485	502	475	490	469
	3									495
	4									481
6	0		462	372	438	471	469	460	457	465
	1									493
	2		548	484	513	540	556	521	538	541
	3									549
	4		577	546	516	535	545	536	583	567
	SEM		11	14	12	14		11		11
Statistical significance of treatment:										
F			NS	NS	**	**		**		**
L			**	**	**	**		**		**
F×*L*			NS	NS	NS	*		NS		**
Wet and dry feeding (*W*/*D*)			—	—	—	NS		*		—
W/*D*×*F*			—	—	—	NS		NS		—
W/*D*×*L*			—	—	—	NS		NS		—
W/*D*×*F*×*L*			—	—	—	NS		NS		—
Difference in lysine response between one and six feeds/d (g/d per 2 g L-lysine per kg diet)			−1	11	21	33	46	29	34	36
Lysine utilization (%)‡			101	90	72	52	47	52	58	31

NS, not significant ($P > 0.05$).
* $P < 0.05$, ** $P < 0.01$.
† For details of diets and dietary regimens, see p. 266 and Tables 1 and 2.
‡ Response to lysine with once daily feeding expressed as a percentage of the response to frequent feeding.

feeding did increase growth rates and decreased food conversion ratios but this appeared to be as a result of its effect of decreasing the dressing percentage. A similar effect also occurred with frequent feeding.

It appears that the results of experiments which have been conducted to observe responses to free lysine under limited feeding regimens need to be interpreted with caution. For example, lysine requirements of pigs based on the response to supplements of free lysine may be over-estimated if full utilization did not occur. This is illustrated by the results presented by Carpenter (1971) when reviewing the problems of assessing nutrient requirements. Carpenter (1971) cited the four estimates used by the Agricultural Research Council's Working Party when assessing the lysine requirements of pigs. The four estimates were 10·9, 13·4, 11·3 and 15·1 g lysine/MJ DE (2·6, 3·2, 2·7 and 3·6 g lysine/Mcal DE) and the Working Party averaged these values to give a final estimate of 12·6 g lysine/MJ DE (3·0 g lysine/Mcal DE). The estimates of 10·9 and 11·3 g lysine/MJ DE were conducted with *ad lib.* feeding, the value of 13·4 g lysine/MJ DE with twice daily feeding and the value of 15·1 g lysine/MJ DE with a 5% feeding scale (no. of feeds not given, presumably one or two, as the daily ration could be consumed in 20 min). It seems probable that the higher estimates could reflect lower utilization of the free lysine and that 11·1 g lysine/MJ DE was a more accurate estimate of the lysine requirement of pigs. It is also possible that the estimation of the other amino acid requirements of pigs could be similarly affected, as lysine is relatively stable, in terms of body turnover rates.

Methods of avoiding inefficient utilization of free lysine supplements for pigs were outlined by Batterham (1974). These appear particularly relevant to the way research is conducted, but the potential benefits to commercial pig production may also be considerable. This applies particularly to 'grower–finisher' diets, where lysine is usually the first limiting amino acid in cereal-based diets. It is also with these diets that restricted feeding is practised in order to produce pigs with carcases of acceptable lean content.

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