The effect of frequency of feeding on the utilization of free lysine by growing pigs

By E. S. BATTERHAM

School of Agriculture and Forestry, University of Melbourne, Parkville, Victoria 3052, Australia

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1. Pigs from 20 to 47 kg live weight were given a wheat–safflower diet supplemented with either 0, 2 or 4 g L-lysine/kg either once daily or in six equal portions at intervals of 3 h.

2. The addition of lysine at both levels significantly ($P < 0.001$) increased growth rate, feed conversion and lean content of the ham.

3. Frequency of feeding had no effect on the response of pigs given the control diet.

4. A significant interaction ($P < 0.05$) between frequency of feeding and lysine supplementation occurred for growth rate. Growth responses to the supplements of 2 and 4 g L-lysine/kg with once-daily feeding were only 43 and 69% of those achieved under the frequent-feeding regimen.

The effects of supplements of free lysine on the performance of pigs given cereal-based diets have been widely examined. Free lysine has been used as a supplement to diets containing protein of poor-to-medium quality, or as a replacement for some of the protein concentrate. Recently lysine, and lysine together with combinations of other amino acids, have been used to replace protein concentrates completely (Braude, Mitchell, Myres, Newport & Cuthbertson, 1972).

However, replacement of a portion of the feed lysine with free lysine has not necessarily resulted in a diet of similar nutritive value. Dent, English & Raeburn (1970), when comparing least-cost formulated diets, observed that inferior pig performance resulted from the diets containing a high proportion of free lysine. The pigs in that study were given their rations twice daily and the authors speculated whether differential rates of absorption of the free and bound amino acids could have impaired utilization. The results of investigations in which the absorption of amino acids in the free and the bound form have been compared in rats have been variable. Gupta, Dakroury & Harper (1958) and Rogers, Chen, Peraino & Harper (1960) found that amino acids in intact protein could be digested and absorbed as quickly as those in the free form. In contrast, Rolls, Porter & Westgarth (1972) found that free amino acids were generally absorbed more rapidly than those derived from protein. The actual absorption rates of protein-bound amino acids have been shown to vary and may be affected by the source of protein, its degree of processing, and the energy component of the diet (Gupta *et al.* 1958; Rogers *et al.* 1960; Goldberg & Guggenheim, 1962; Buraczewski, Porter, Rolls & Zebrowska, 1971). As a result Gupta *et al.* (1958) and Porter & Rolls (1971) have emphasized that, unless similar rates of digestion and absorption of all sources of amino acids occur, the efficiency of utilization of the whole diet may be impaired.

Table 1. *Composition (g/kg) of the diets*

Ingredient	Diet 1	Diet 2	Diet 3
Wheat	804·9	804·9	804·9
Safflower meal	160·0	160·0	160·0
Minerals and vitamins*	30·0	30·0	30·0
L-Lysine hydrochloride†	—	2·55	5·10
Starch	5·10	2·55	—

* Contributed per kg dry matter in diet: Fe 30 mg, Zn 100 mg, Mn 30 mg, Cu 5 mg, I 2 mg, Se 0·15 mg, salt 2·5 g, retinol equivalent 960 μg, cholecalciferol 12 μg, α-tocopherol equivalent 7 mg, thiamin 1 mg, riboflavin 3 mg, nicotinic acid 24 mg, pantothenic acid 10 mg, pyridoxine 1·5 mg, cyanocobalamin 15 μg, pteroylmonoglutamic acid 2 mg, choline 500 mg, ascorbic acid 10 mg.

† L-Lysine monohydrochloride, anhydrous, 98% feed-grade, containing 78% L-lysine and manufactured by Kyowa Hakko Kogyo Co. Ltd, Japan.

If there was a differential rate of absorption between a free amino acid supplement and the basal diet, then the efficiency of utilization would be likely to be most affected if a single large meal was given daily and to decrease as the frequency of feeding increased. Such an effect would be particularly relevant to the use of lysine with pigs because in many countries they are fed once or twice daily. In the work described here, an experiment was made to examine the efficiency of utilization of free lysine when given to pigs fed once daily.

EXPERIMENTAL

Diets and treatments

Wheat and safflower were used as the basis of a diet deficient in lysine (Table 1) but containing sufficient amounts of other amino acids to allow a growth response to the lysine supplement of approximately 20–30%. This diet was then supplemented with either 2 or 4 g L-lysine/kg. The level of 2 g L-lysine/kg was chosen to observe the response to lysine under the two feeding regimens in conditions in which the full utilization of the added lysine should be obtained. The 4 g/kg level of L-lysine was chosen to show that the diets supplemented with 2 g L-lysine/kg were in fact still lysine-deficient.

The three diets were given either once daily or in six equal portions. The once-daily feeding was at 08.00 hours and the six feeds were at 08.00, 11.00, 14.00, 17.00, 20.00 and 23.00 hours. Feeding at intervals of 3 h was chosen because Gupta *et al.* (1958) and Rogers *et al.* (1960) reported that approximately 50% of a given amount of food passed through the stomach in 3 h, and thus by feeding at this frequency a reasonably constant flow of material for absorption should have been achieved.

The dietary ingredients (Table 2) were analysed by the following techniques: acid-detergent fibre (Drennan & Maguire, 1970), crude protein and diethyl ether extract (Association of Official Agricultural Chemists, 1965), tryptophan (Miller, 1967), cystine and cysteine (Jamalian & Pellett, 1968), available lysine (Roach, Sanderson & Williams, 1967), other amino acids (Spackman, Stein & Moore, 1958). The digestible energy of the control diet was determined with three pigs in metabolism crates, two collection periods being used.

Table 2. *Chemical composition of the ingredients and of the control diet*

	Wheat (g/kg)	Safflower (g/kg)	Control diet* (g/kg)
Crude protein	121	507	179
Moisture	120	87	111
Diethyl ether extract	34	15	30
Acid-detergent fibre	30	204	57
Amino acids	(g/16 gN)	(g/16 gN)	(g/kg)
Tryptophan	1·07	1·22	2·0
Lysine	2·58	2·94	4·9
Available lysine	2·40	2·70	4·5
Histidine	2·09	2·34	3·9
Arginine	4·25	8·29	10·9
Aspartic acid	4·61	9·96	12·6
Threonine	2·77	2·91	5·1
Serine	4·56	4·22	7·9
Glutamic acid	28·38	19·15	43·2
Proline	8·55	4·42	11·9
Glycine	3·84	4·85	7·7
Alanine	3·30	3·90	6·4
Cystine + cysteine	2·07	1·44	3·2
Methionine	1·24	0·81	1·9
Valine	3·57	5·25	7·7
Isoleucine	3·32	3·57	6·1
Leucine	5·90	5·66	10·3
Tyrosine	2·27	2·77	4·5
Phenylalanine	3·90	4·37	7·3

* Contained 13·8 MJ (3·30 Mcal) digestible energy per kg.

Animals and procedure

The six dietary treatments were arranged in a 2×3 factorial design. There were eight replications, each consisting of six Large White or Large White ♂ × Landrace ♀ pigs, which were selected and allotted to treatments on the basis of 7-week weight, breed and sex. Four replications were females and four castrate males. The pigs were penned individually in a building maintained at a temperature of $22 \pm 1°$. Water was supplied by nipple drinkers. The pigs were trained to consume approximately 1000 g of a 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 feed was offered dry with the frequent-feeding regimen but with the once-daily feeding system some water (approximately 1 part water to 3 parts feed) was added to the feed to help the pigs to consume their ration in 20–30 min.

The pigs were slaughtered after reaching a minimum weight of 45 kg. The ham was dissected and the percentage lean used as an indicator of carcass leanness. Pig response was assessed in terms of live-weight gain/d, food conversion ratio (kg food eaten/kg live-weight gain) and percentage lean in the ham. The results were analysed statistically according to Snedecor & Cochran (1967).

Table 3. *Effect of frequency of feeding on the utilization of free lysine by pigs during the 20–47 kg growth period*

Feeding regimen	Live-wt gain (g/d)	Food conversion ratio*	Lean in ham (g/kg)
One feed/d			
Control	451	3·05	634
+2 g L-lysine/kg diet	483	2·77	655
+4 g L-lysine/kg diet	526	2·59	665
Six feeds/d			
Control	438	3·09	631
+2 g L-lysine/kg diet	513	2·67	667
+4 g L-lysine/kg diet	546	2·52	680
Statistical analyses†			
Frequency of feeding	NS	NS	NS
Control *v.* lysine	***	***	***
Interaction with frequency of feeding	*	NS	NS
2 g *v.* 4 g L-lysine/kg diet	***	**	NS
Interaction with frequency of feeding	NS	NS	NS
SEM (35 df)‡	9·4	0·052	6·1

* kg food eaten/kg live-weight gain.
† NS, not significant ($P > 0·05$); $*P < 0·05$; $**P < 0·01$; $***P < 0·001$.
‡ 33 df for lean in the ham, as two hams were misplaced at the abattoirs and missing values were used in the analysis.

RESULTS

The addition of lysine at both levels significantly ($P < 0·001$) increased growth rate, and percentage lean in the ham and reduced the feed-conversion ratio (Table 3).

Frequency of feeding had no effect on the response of pigs given the control diet. However, for weight gain, a significant interaction ($P < 0·05$) occurred between frequency of feeding and lysine supplementation. Increased weight gains on diets supplemented with 2 and 4 g L-lysine/kg for the once-daily feeding routine were only 43 and 69% of those achieved with the frequent-feeding regimen.

Similarly, with the frequent-feeding regimen feed conversion ratio tended to be reduced and percentage lean in the ham tended to be increased but these effects did not reach statistical significance.

DISCUSSION

To estimate the efficiency of utilization of lysine it is necessary to ensure that the supplemented diet is still lysine-deficient so that the supplementary lysine has been given the opportunity to be fully utilized, within the constraints of the feeding regimen. The increased response to the L-lysine supplement at the 4 g/kg level over that at the 2 g/kg level for growth and food conversion efficiency with both feeding systems indicates that a comparison can be made at the 2 g/kg level. Thus with once-daily feeding, free lysine was used with an efficiency of 43% relative to that with frequent feeding. Absolute utilization may have been less, as the utilization of the lysine with frequent feeding may not have been 100%. A similar comparison cannot be made at the 4 g/kg level since the apparent utilization of lysine of 69% appears to have been due to inefficient utilization of lysine at the 4 g/kg level with frequent feeding (as a result of a surplus being provided) rather than to an increase in the efficiency of use of the extra increment of lysine with once-daily feeding. This is supported by the growth results, which show a rectilinear response to the increments of lysine for once-daily feeding and a decreasing response for frequent feeding.

Addition of water to the feed was not necessary for the pigs fed six times daily as they were able to consume the small amounts of feed given without needing to drink. However, the addition of water to the feed of the pigs fed once daily helped the pigs to consume their rations quickly, since time was not wasted during feeding by the pigs going to the drinkers at the back of the pens. It seems unlikely that the results were affected by this addition of water, since there was no difference in the performance of pigs offered the control diet under the two feeding regimens.

The application of these results needs to be treated cautiously. It seems reasonable that absolute rates of absorption of free lysine will be similar with different batches of feed-grade lysine but the absorption rate of amino acids from the basal diets may vary, depending on other factors outlined on page 237. However, lysine requirements based on the response of pigs to free lysine added to a diet at varying levels may be over-estimated if once-daily feeding is used. In practice, many experiments have been made with twice-daily feeding, but even here there may have been some over-estimation as the interval between the two feeds is usually 6 h or more. On the other hand, when feeding is *ad lib.* it is unlikely that utilization of the lysine will be affected.

The potential for the use of free lysine in diets for pigs is considerable (as it is for other non-ruminants) and it appears necessary that attempts be made to avoid inefficient utilization. To attempt to compensate for the low utilization by increasing the amount of free lysine would seem both economically wasteful and potentially dangerous nutritionally, as it may lead to imbalances. A better approach would be to attempt to balance the arrival of the protein-bound amino acids and free lysine at the site of absorption. To achieve this by attempting to increase the rate of release of the protein-bound amino acids may be wasteful as it may oversaturate the utilization processes (Porter & Rolls, 1971). Thus the answer is apparently to delay the rate of absorption of free lysine. This could be achieved by developing a slow-release lysine compound, by offering the lysine at a suitable interval of time after the basal diet, or by increasing the frequency of feeding. With pigs, a simple management solution may be to feed *ad lib.* to 45 kg, and then in restricted amounts to 80 kg live weight; the lysine supplement may be necessary only in the early growth stage, when the pig's requirement for lysine is greatest.

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