MEETING THE NUTRIENT REQUIREMENTS OF GROWING PIGS

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Summary

This paper outlines a system of meeting the nutrient requirements of pigs based on physiological information. This enables daily requirements to be related more closely to specific levels of production of lean and fat. Attention is drawn to the way in which digestibility of feed ingredients, diseases and drugs can have a marked effect on efficiency of production.

I. INTRODUCTION .

The Agricultural Research Council (1967) and the National Research Council (1968) and (1973) both attempted to estimate the nutrient requirements of pigs. A comparison of the English and American publications indicates marked differences which must be regarded as challenging and in need of explanation.

In recent years Whittemore and Fawcett (1974), (1976); Whittemore and Elsley (1976) and Thorbek (1975) have presented information which should I think change our approach to the problem of meeting the nutrient requirements of pigs.

In the past, nutritionists have spent much time searching for the ideal feed formulation and the ideal balance of amino acids. These attempts have been confounded due to wide variations in:-

(a) Daily feed intake
(b) Growth potential of the pig
(c) Nutrient availability
(d) Market requirements
(e) The pigs environment
(f) The effects of diseases

Once nutrient requirements are considered on a daily basis to meet defined targets of fat free growth and adipose tissue then the requirements are more easily defined and understood.

Whittemore and Fawcett (1974), (1976) have computer programmed a model of the growing pig which is based on physiological information incorporated into a series of linked equations. The model allows for differences in:-

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(a) Maximum potential daily protein deposition
(b) Daily feed intake
(c) Dietary specifications
(d) Starting weight and slaughter weight or age
(e) Temperature of the environment
(f) Carcase quality expressed as backfat thickness at P_2

This model simulates the growth of the pig on a daily basis and its predictions quite closely match the results from live pig experiments.

The fact that this approach has resulted in a successful model strongly supports its validity and indicates areas in which future research holds most promise.

This paper discusses the nutrient requirements of growing pigs in terms relating to Whittemore and Fawcett's (1974) (1976) model. The subject is considered under the following headings

II Composition of the growth of a pig
III Protein requirements
IV Energy requirements
V Vitamins, minerals, water and essential fatty acids
VI Nutrient digestibility and availability
VII Effects of stress, disease and feed medications

II COMPOSITION OF THE GROWTH OF THE PIG

Most of the value of pigmeat is in the lean meat and as it can be produced more efficiently than fat, its successful production is the key to profitability. For this reason much effort has been devoted to improving the lean content of pigmeat by breeding, management and nutrition.

TABLE I

Chemical Composition of Growing Pigs

Empty Live Wt.	Percentage Composition of Tissues			
Kg	Water	Protein	Lipid	Ash
Birth	81	11	1*	4
5	68	13	12	3
10	66	14	15	3
15	64	15	18	3
20	63	15	18	3
36	58	17	22	3
52	54	16	27	3
71	52	15	30	3
100	46	14	38	3

* The new-born pig contains 2.5% glycogen.

Values birth to 20 kg Whittemore and Elsley (1976)
Values 36 to 100 kg calculated from McMeckan (1940)

The following points should be noted in Table I:

(a) As growth proceeds, water is gradually replaced by fat
(b) Ash content drops soon after birth and is uniform thereafter
(c) Protein content shows little change .

Priorities for growth are recognised to be first skeletal development then muscle growth and then any surplus energy absorbed is laid down as fat. The maximum rate of lean tissue growth is in the region of 450 g per day. Thus any growth in excess of this can be assumed to be fat. Growth up to 550 g per day is in the ratio of one part protein to one part fat, that is each 100 grams of gain will be made up of 20 g fat and 80 g lean, the latter containing 20 g protein.

For any one pig the maximu'm rate that nitrogen can be deposited is remarkably constant from 20 to 120 kg liveweight. This maximum is controlled by the pigs sex and genetic potential. The expected variations are shown in Table (2).

TABLE 2

Maximum daily rates of nitrogen, protein and lean deposition g/d.

Pig	Nitrogen	Protein	Lean
Unimproved	11.2	70	310
Improved	17.6	110	480
Castrate	14.4	90	400
Gilt	19.2	120	530
Boar	21.6	135	590

Young pigs often have difficulty in eating sufficient energy until they reach 30 to 40 kg liveweight. This tends to reduce lean growth to below the pigs potential.

Variations in the amount of fat in a pig become more apparent as growth proceeds. These variations are most important at time of slaughter. The backfat thickness at P2 can be used to estimate the fat in the carcase as shown in Table 3 and from this the rate of protein deposition can be calculated.

In Table 3 is tentatively shown the relationship between backfat thickness of 100 kg pig at P2 and the percent fat in the carcase as used in the model by Whittemore and Elsley (1976). Extrapolation is used to indicate the possible composition of the live pig and the rate of protein deposition assuming growth rates of 500 g/d and 650 g/d from 20 kg liveweight.

TABLE 3

Backfat Thickness P2 m m	Fat in Carcase %	Fat in Live Pig Kg	Protein in Live Pig Kg	Daily Protein deposition (g) at Daily Gains of - 500 g	650 g
16.7	20	16	17.6	91	119
20.8	25	20	16.4	84	109
25	30	24	15	75	97
29.2	35	28	13.8	68	88
33.3	40	33	13.1	63	82
37.5	45	37	11.2	51	67

III PROTEIN REQUIREMENTS

Having discussed the manner of lean growth and given an indication in Tables (2) and (3) on the rate at which protein is deposited under defined circumstances, it is relatively straightforward to define protein requirements.

The protein requirements of growing pigs are made up of several components:-

(a) The protein requirement for maintenance is a function of lean mass and varies from about 0.12% of body weight in small pigs to 0.05% of body weight in large pigs.
(b) Lean growth contains about 22% protein.
(c) Dietary protein must then be adjusted to allow for its biological value and digestibility.

Thus the requirement for dietary crude protein may be calculated as shown by the examples in Table (4).

TABLE 4

Calculations of daily dietary crude protein required under the conditions specified

Liveweight	40 kg	80 kg
Maintenance	0.1% of 40kg = 40g	.07% of 80 kg = 56 g
Rate of lean growth	310 g	450 g
Protein required for growth	68 g	99 g
Total protein required	108 g	155 g
Allow biological value of	60%	65%
Digestible protein required	180 g	238 g
Allow for digestibility	75%	80%
Crude Protein required	240 g	298 g

Amino Acid Requirements

Table(5) shows (a) the levels of amino acids that protein should contain for growing pigs as suggested by Whittemore and Elsley (1976). For comparison the recommendations of the AEC 1978 have been extrapolated (B) and shown on similar terms so they may be compared.

TABLE 5

	A	B
Lysine %	5.5	5.8
Threonine %	3.2	3.2
Methionine + Cystine %	3.1	3.5
Tryptophan %	1.0	1.0
Histidine %	1.5	1.7
Leucine %	5.0	4.0
Isoleucine %	3.5	3.5
Valine %	3.5	3.5
Tyrosine + Phenylalanine %	3.5	3.5

Some studies done in the past on amino acid requirements will now need re-appraisal in order to bear in mind the following points:-

(a) It has been shown that the availability of synthetic lysine is dependant on the frequency of feeding. Batterham and O'Neil (1978) showed that only 67% of synthetic lysine was available when fed once daily by comparison with feeding six times daily at three hour intervals.

(b) It seems that low protein diets supplemented with high levels of synthetic lysine are capable of excellent growth rates and reduced backfat measurements but that protein deposition and feed conversions are not quite restored. (A.E.C. (1975); Campbell (1977)). This point is more apparent when allowance is made for the likely increase in net energy of diets with lower levels of protein meals.

(c) It has been shown that lysine requirements are reduced as surpluses of other amino acids are eliminated. Lysine requirement is increased by 0.2g for each 10g of surplus crude protein present.

IV ENERGY REQUIREMENTS

The requirements of energy for maintenance are stated by Whittemore and Elsley (1976) to be between 0.4 and 0.5 MJ of metabolisable energy per kilogram of metabolic weight (i.e. liveweight$^{0.75}$).

For production, energy is required in the protein and fat laid down and energy is also required to drive the processes. Most of the energy used in driving the growth process is lost as heat.

TABLE 6

Energy requirements for protein and fat deposition

	Protein	(Lean)	Fat	(Adipose)
MJ energy in 1 kg deposited	24	5.5	39	35.5
MJ energy to drive processes	45	10.4	14	12.7
Total energy required MJ	69	15.9	54	48.2
Efficiency %	35		72	

It should be noted from Table (6) that more energy is required to lay down protein than fat. However, when lean tissue is compared to adipose tissue, then only one third the amount of energy is required for lean growth. The actual energy required for protein growth varies between 45 and 80 MJ/kg protein. The high and variable requirements for driving the process of depositing protein are mostly due to the protein being constantly recycled, the quantities being proportional to the lean mass. About 7.5 MJ ME/kg new protein is required to rearrange the amino acids.

If a pig is in a cold environment and is losing heat faster than normal metabolism has to spare, then extra heat has to be made available to maintain body temperature. Thus there is less energy available for production. The lower critical temperature at which no production losses are suffered is therefore dependant on the heat output of the pig. This in turn is dependant on the pig's size and productivity. Table (7) shows the estimated lower critical temperature once the pigs heat output is known. Also shown is the weight a pig would be in order to produce that heat if it was growing at an average rate.

TABLE 7

Pigs heat output MJ/d	Liveweight kg	Lower Critical Temp °C
5	9	25
10	21	21
15	37	17
20	54	14
25	73	10
30	93	7

Note that at average growth rates the heat output in MJ is close to the value for metabolic body weight.' Pigs having depressed growth rates have higher Lower Critical Temperatures. For each degree centigrade of environmental temperature below a pig's Lower Critical Temperature that pig will need 0.016 MJ of ME per kilogram of metabolic body weight daily to maintain body heat.

TABLE 8

Summary of Approximate Energy Requirements for Growing Pigs

Maintenance	-	0.5 MJ DE/kg	Metabolic body weight
Lean Growth	-	15 MJ DE/kg	Lean formed
Fat Growth	-	50 MJ DE/kg	Fat formed
Cold	-	0.017 MJ DE/kg	Metabolic body weight/°C of cold

Examples of estimates of energy requirements are as follows:

A. Pig 50 kg growing at 600 g/d with protein adequate for 400 g lean growth daily.

Maintenance	50 kg	18.8 x 0.5	=	9.4 MJ DE
Lean		.400 x 15	=	6.0 MJ DE
Fat 600-400		.200 x 50	=	10.0 MJ DE
Total energy requirement				25.4 MJ DE

B. Pig 40 kg eats 1.7 kg feed containing 12.5 MJ DE and sufficient protein for 350 g of lean growth daily. The temperature in the pen is 15°C.

Approximate LCT	= 17°C		
Maintenance 40 kg	15.9 x 0.5	=	7.95 MJ DE
Lean 350 g	.35 x 15	=	5.25 MJ DE
Cold 2°C below LCT	2 x 15.9 x 0.017	=	0.54 MJ DE
Energy required for maintenance lean growth and cold			13.74 MJ DE
Energy for fat	1.7 x 12.5 - 13.74	=	7.51 MJ DE
Fat deposited	7.51 - 50	=	150 g
∴ Total daily gain	350 + 150		500 g

V VITAMINS, ESSENTIAL FATTY ACIDS, MINERALS AND WATER

Shown in Table (9) are the estimates of the ARC (1967) and NRC (1973) for the total requirements of vitamins and minerals together with the levels that the AEC (1978) recommends should be added per kg of feed.

TABLE 9

	ARC	NRC	AEC
Vit A i.u. up to 20 kg	1400	1800	10,000
20-60 kg	1600	1300	5,000
60-100 kg	1900	1300	5,000
D3 i.u.	230	200	1,000
E i.u.	1.5	11	12
K mg	-	-	0.3
Thiamine mg	1.5	1.1	-
Riboflavin mg	2.5	3-2.2	3.5-2.5
Niacin mg	20-12	22-10	15-12
Pantothenic Acid mg	10	13-11	10- 8
Pyridoxine mg	2.5	+	-
Vitamin B_{12} mg	.018-.01	.022-.011	.025-.015
Choline mg	870	1100	1200-900
Biotin	+	+	-
Folic Acid	+	+	-
Ascorbic Acid	-	-	-
Lindeic Acid g	-	2.2	-
Ca g	8 - 6	8 - 6	10 - 7.5
P g	7 - 5	6 - 4	8 - 6.5
Salt g	2.5	2.5	4
Potassium g	2.5	2.6	-
Magnesium g	0.4	0.4	-
Iron mg	60	80	50
Zinc mg	50	50	125
Manganese mg	+	20	40
Copper mg	4	6	13
Cobalt mg	(as Vit B_{12})	0.1	0.5
Iodine mg	+	0.2	0.5
Selenium mg	-	0.1	0.06
Fluorine	-	-	-
Molybdenum	-	-	-

\+ Requirement established but not estimated
\- No requirement given
Where a range of figures are shown the higher level is for piglets

Vitamin E: Recent published studies indicate that pigs probably require about 15 i.u. per kilogramme of feed.

Biotin: There have been field reports of pigs with cracked heals, slight dermatitis and alopecia responding to treatment with biotin. Pigs on wheat and meat meal diets in stalls or tethered may benefit from a biotin supplement.

Ascorbic acid supplements have been reported to improve pig performance under hot conditions and conditions of stress. However, most pigs thrive without dietary ascorbic acid by being able to synthesise it so there are grave doubts that the pig requires a dietary source of ascorbic acid. It seems that severely stressed piglets getting very little feed may benefit from supplements of ascorbic acid because their dietary energy intake is so inadequate.

Calcium and Phosphorus: The low requirements indicated by the NRC would apply to corn soyabean diets relatively low in phytate phosphorus and supplemented with readily available phosphorus. Even on that basis, there are many nutritionists who prefer to use the higher levels indicated by A.E.C. On a long term basis, it seems advisable to maintain the calcium to phosphorus ratio within the range of 1.2 to 1.4 of calcium to one of phosphorus.

Zinc: Zinc requirements are considerably increased in the presence of high levels of calcium, phytic acid and copper. Supplements of 100 mg per kilogramme of feed are commonly used and seem to be needed sometimes.

Molybdenum: I have included molybdenum in recognition of the quite widespread incidence in Australia of the "scabby hip" syndrome in broilers. This condition is responsive to molybdenum so it might be advisable to add say 0.2 - 2 mg per kg of feed. There is no data on the requirement but it should be noted that 3 mg molybdenum per kg feed is toxic to ruminants while pigs are reported to be able to tolerate levels of up to 1,000 mg/kg feed.

Water: Water is usually available ad libitum and the pig allowed to adjust its own requirements. It is of course of paramount importance being essential to metabolism and homeostasis.

Where supplies are scarce, water should be provided twice daily. The pig should be allowed at least two litres of water for each kilogramme of feed. Considerably more should be provided under hot conditions.

VI NUTRIENT DIGESTIBILITY AND AVAILABILITY

A very important task in meeting the nutrient requirements of growing animals lies in defining the digestibility of feed ingredients and the availability of the nutrients. Ingredients in a ration can interact with each other. Rationing programmes and diseases can all influence digestibility and availability of nutrients.

Shown in Table 10 is the approximate composition of one kilogramme of dry feed and the residues likely to be found in. the faeces from the original one kilogramme of feed.

TABLE 10

	Gross Energy MJ/kg	Feed	Faeces	% Digestibility	D.E. MJ/kg
Dry matter		1000	179	82	15.47
Carbohydrates	17.4	700	72	90	10.96
Fat	39.3	50	14	72	1.41
Protein	23.6	150	23	85	3.01
Fibre	17.4	50	45	10	0.09
Ash		50	25	50	

Table (10) also shows the digestibility of the feed and the effect digestibility has on the energy yield of the feed. The fate of energy is shown in figure 1

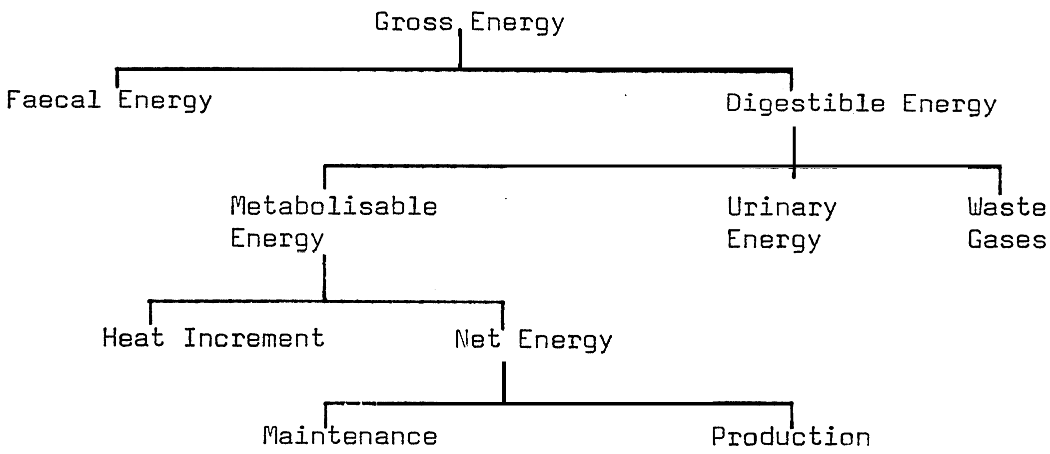

Figure 1: Partitioning of food energy by the pig

The digestible energy of feed ingredients can be most readily determined in pigs. Net energy or metabolisable energy values are more subject to variations due to the pig and its environment and therefore may not fairly represent the feed. It should be noticed that protein is higher in energy than carbohydrates. Only about half of the digested protein goes into the formation of new protein growth, the remaining protein is deaminated resulting in considerable energy losses so that the energy yield of deaminated protein is only about half that of the original digested protein. The energy losses in deaminating surplus protein explain why pigs on diets containing surplus protein suffer a deterioration in growth rate and feed conversion when in fact digestible energy intakes have been maintained. Correcting an amino acid deficiency improves efficiency by increasing protein deposition and reducing energy lost by deaminating the unbalanced supply of amino acids.

Digestibility studies in pigs have mostly been carried out by comparing the analysis of the feed eaten with the analysis of the residues in the faeces. For proteins an adjustment should then perhaps be made to allow for metabolic faecal losses and protein lost and gained as a result of fermentation especially in the caecum. Protein digested in the small intestine makes up the supply of amino acids to the pig. Protein which is subject to fermentation in the large intestine cannot make any contribution to the protein requirements of the pig and may well mislead studies on digestibility of amino acids. These fermentations also generate volatile fatty acids which are absorbed and contribute to the pig's energy requirements.

Figure 2' shows the partitioning of feed protein by the pig.

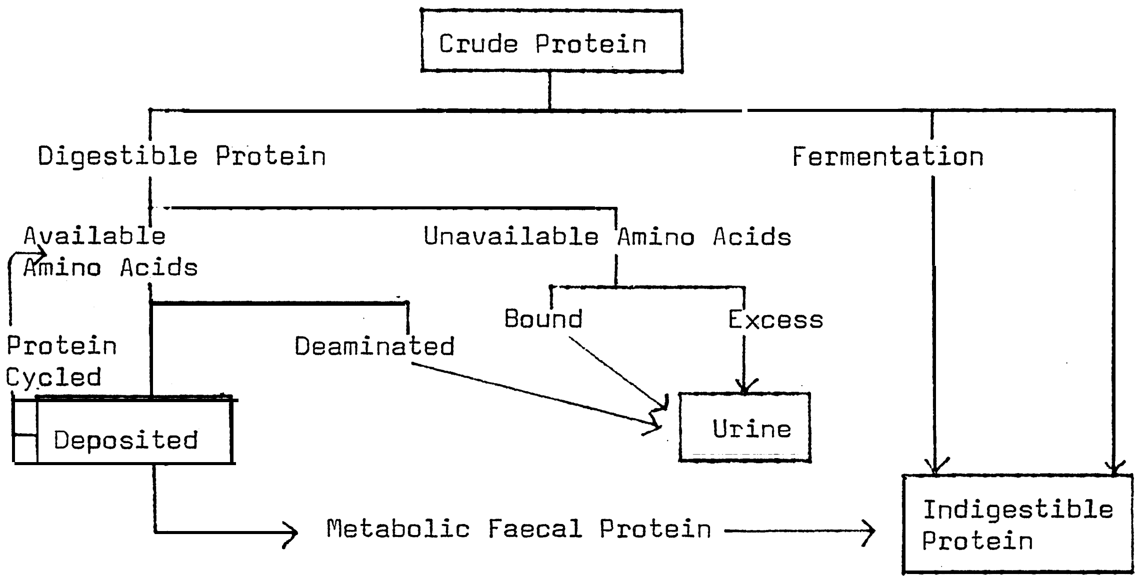

Figure 2: Partitioning of food protein by the pig.

It will be seen from this that attempts to measura available amino acids by measuring disappearance should be done at the terminal ileum to avoid distortions due to fermentation in the hind gut. Even if this is done some account should be given for metabolic faecal protein and the possibility of some absorbed amino acids being unavailable. For more detailed reviews on protein digestion reference can be made to the reviews of Miller (1976) and Purser (1976).

Inhibitors and Heat Damage

Many feed ingredients contain compounds which can inhibit digestibility of the protein. The presence of a protease inhibitor and a haemaqglutinin in raw soyabeans is probably the most familiar example. Similar inhibitors have been detected in other beans and also in rye, barley, wheat, triticale, lucerne, potatoes and many other ingredients. It seems that an inhibitor in one ingredient can adversely affect the whole ration if it is present in sufficient quantities. It has been reported that germ free chicks are far less susceptible to the adverse effects of raw soyabean. This indicates that the animals normal intestinal micro-organisms probably have some role in the adverse effects. The adverse effects of these protein inhibitors can be prevented by suitable cooking of the ingredient.

Gossypol in cottonseed meal and tannins in sorghum bind with protein and reduce the availability of the'amino acids.

Any heat tends to reduce the digestibility of proteins. Carefully controlled drying of grains and cooking of soyabean should only reduce digestibility about five percent but excessive cooking can reduce digestibility to below 50%. It would appear that the digestibility of meat meal is often severely affected. The presence of reducing sugars makes the protein more vulnerable to the adverse effects of heat damage. Chemical tests for available lysine have been widely used especially on fish and meat meals but Batterham, Murison and Lewis (1978) were not able to correlate the Silcock estimates with their rat or pig bio-assay estimates.

Feed Particle Size, Pelleting and Intestinal Transit Times

Digestive enzymes take time to act and they need to be able to penetrate the feed particles. For this reason fine grinding assists digestion and factors that cause feed to pass rapidly through the intestine result in reduced digestibility. The digestibility of energy in grain is only about 60% for whole grain, 73% for broken grain., 80% for coarsely ground and 85% for finely ground. The actual performance of a sample of feed will depend on numerous other factors.

The digestibility of wheat for instance can be reduced by fine grinding because it can form a somewhat indigestible dough.

Digestibility tends to decline with increasing fibre in the diet. Young pigs are more susceptible to this by comparison with dry sows on restricted feed. The latter are capable of digesting significant amounts of fibre in the large intestine aided by micro-organisms. The latter does not help protein digestibility but it can contribute to energy supplies.

Numerous experiments have demonstrated improvement of pig performance by pelleting of feed. Barley based rations and those containing pollard and bran have shown the best response whereas responses with corn based rations tend to be lower. There has been much conjecture about the explanation for this. Most agree feed wastage is reduced and some have demonstrated an improvement in the availability of phosphorus. Saunders, Walker and Kohler (1969) working with chickens examined faeces under the microscope. They reported that pelleting increased the proportion of aleurone cells which were ruptured and empty by comparison with the numbers that still appeared intact. Auto-claving bran reduced digestibility presumably due to the Maillard reaction so it is presumed the benefit is from the physical disruption of the cells through the die. The steam conditioning probably assists the disruption.

VII EFFECTS OF STRESS, DISEASE AND FEED MEDICATIONS

No one would dispute the importance of stress and disease on the performance of pigs. There are unfortunately few studies on the effect of stress and disease on the nutrient requirements of pigs. Enzootic pneumonia and mange are somewhat insiduous in their effects but are amongst the most costly diseases affecting pig production. Growth rate is reduced, metabolic rate increased and under conditions of group feeding affected pigs usually eat less feed. Deteriorations in feed conversion in the region of 8-15% have been quoted for each of these diseases.

Social stress contributes substantially to the differences between individuals in a pen of pigs. Social stress can be reduced by housing pigs in single litter groups in the same pen from birth to slaughter. Such pigs are said to reach bacon weight two weeks quicker than the more usual methods of mixing and moving groups of pigs. Ostrowski stressed a pig in a metabolism cage by pulling at a ring in its nose. He showed that the stress could drop digestibility of the feed from 75% to 50%. Thus stress could well be interfering with research efforts on defining nutrient requirements as well as in commercial piggeries.

A wide variety of drugs have been found to improve the performance of pigs when they have been added to the feed. Quite high levels of some drugs have been used to help the control of disease probelms in young pigs. Up to 20 to 30 kg liveweight improvements in the region of ten percent have been reported in both growth rate and feed conversion. The response shown by larger pigs is very much smaller but can nevertheless be profitable. Apart from medications aimed at controlling specific pathogens much uncertainty still surrounds the mode of action of these drugs. It should be noted that there is considerable variation in the responses to these drugs from one piggery to another and at different times.

In view of the magnitude of the pigs responses to stress, diseases and drugs in feeds, it leaves some doubt about how the nutritionist should best adjust the ration to make the best compromise with these variables.

CONCLUSION

Whittemore and Fawcett (1976) have demonstrated the validity of a model to simulate a growing- pig. This model has shown the need to define carefully the potential of the pig. for lean growth. It has also shown the importance of the daily ration given the pig and the manner in which this controls the pigs growth. It is apparent that quite substantial areas of uncertainty exist relating to digestibility and availability of nutrients especially the protein supply of the pig. In the light of recent findings on the availability of synthetic lysine more work seems to be needed in order to relate essential amino acid supplies to daily requirements of a pig with a defined potential for lean growth.

REFERENCES

AEC Department Alimentation Animale (1975) Pigs 451

AEC Department Alimentation Animale (1978) Animal Feeding, Document No. 4

Agricultural Research Council (1967) The Nutrient Requirements of Farm Livestock No. 3 Pigs H.M.S.O. London

Batterham E. S. & O'Neil G. H. (1978) Br. 3. Nutr. 39 259

Batterham E. S., Murison R.D. and Lewis C. E. (1978) Br. 3. Nutr. 40 23

Campbell R. G. (1977) Recent Advances in Amimal Nutrition University of New England

McMeekan C. P. (1940) 3. Agric Sci Camb 30 387

Miller E. L. (1975) Reviews in Rural Science II p 47 University of New England

National Research Council - Nutrient Requirements of Swine 6th Edition 1968; 7th Edition 1973 National Academy of Sciences Washington D.C.
Ostrowski N.Z.J. of Ag. Res. 17 p 305
Purser D.B. 1975 Reviews in Rural Science II p 39 University of New England
Saunders R.M., Walker H.G. Jr and Kohler G.O. 1969 P.Sci 48 p 1497
Thorbek G 1975 Beretning fra Statens Husdyrbrugsforsog No. 424
Whittemore C. T. and Fawcett R. H. 1974 Anim. Prod. 19 p 221
Whittemore C. T. and Fawcett R.H. 1976 Anim. Prod. 20 p 87
Whittemore C.T. and Elsley F.W.H. 1976 Practical Pig Nutrition Farming Press England