THE PROTEIN AND AMINO ACID REQUIREMENTS OF SOWS

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Summary

In a discussion of some of the problems involved in determining the protein requirements of sows, attention is drawn to the differential response of the several components of reproductive performance to protein intake, to uncertainty as to their relative economic importance, and the multiplicity of criteria that have been used in assessing adequacy. Recent studies of protein and lysine requirements during gestation and lactation are reviewed. It is concluded that although the use of all-cereal diets during gestation have generally proved unsatisfactory considerable savings are possible in the protein supplementation of both gestation and lactation diets so long as daily intakes of amino acids, especially lysine, are in line with those recommended by the NRC (1973). Much still remains to be learned about the protein nutrition of the sow particularly in relation to conditions in this country. The formulation of sow diets which are aimed at economic, rather than biological, efficiency has yet to be attempted.

I. INTRODUCTION

The literature concerning the energy and protein nutrition of the sow has increased substantially during the last decade. Although in some respects the evolving picture has become clearer there remains much uncertainty and there is still a dearth of information of some fundamental aspects.

Before surveying some of the newer information relating to protein needs, it is useful to consider why the quantitative relationships between nutrient inputs and response and their application to sow feeding are not easily elucidated.

II. SOME PROBLEMS IN ESTABLISHING THE NUTRIENT REQUIREMENTS OF SOWS

The first problem is the sow herself. Not only do sows within the same herd differ appreciably in reproductive performance but individual animals also vary in this respect from one parity to another. This inherent variability is compounded by the sow's marked capacity to buffer her litter, both pre- and post-natally, against the effects of nutritional inadequacies in her diet. Taken together these two factors imply that in order to obtain meaningful results nutritional experiments need to involve large numbers of animals and be continued over at least three parities and, preferably, even longer.

The second problem relates to the fact that in. a multiparous species such as the pig reproductive performance has several facets, all of which are of considerable, though differing, economic importance. Thus sows are required not only to produce and rear large and heavy litters but also to come into oestrus and conceive within a few days of weaning their previous litter. They are expected to repeat this cycle at least five or six times,

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so that the maintenance of an adequate level of body condition is also of concern. Finally, there are the questions of the biological and economic efficiencies of the whole process, particularly in relation to food inputs. In consequence, in feed experiments involving lactating animals it is usual to record at least a dozen but up to 40 (Elsley, MacPherson and McDonald 1971) different parameters covering these several aspects of reproductive performance. The fact that experimental treatments usually affect these parameters differentially leads to confusion as to the practical significance of the results. The situation is well summarised in a recent comment concerning protein requirements by Elsley (1976) that "the absence of a useful specification of the optimum protein needs of sows or the description of the response function of protein intake and performance is probably due as much to the range of criteria that have been used to assess the needs of the sow as to-the variation in response attributable to environmental or genetic variables".

A third set of difficulties relate firstly, to variation in the results obtained by different experimental techniques and secondly, to lack of uniformity in experimental methods. In studying the protein (and energy) nutrition of the sow four approaches have been adopted, namely, factorial estimation of nutrient requirements, direct balance determination, monitoring of blood metabolites, and sow productivity. Elsley (1976) has discussed the respective limitations of these techniques. Earlier, Elsley and MacPherson (1972) had concluded that "the estimates of protein requirements based on field trials and which involve direct measurement of reproductive performance are lower than those based on either the factorial or nitrogen retention approaches". The latter approaches are likely to make a greater contribution in the future. Nevertheless, large-scale feeding experiments will continue to be of major importance since the long-term response of the sow under conditions which, as far as practicable, approach those occurring in practice is the ultimate determinant of nutritional adequacy.

In considering the results of sow experiments it is essential to be aware of differences in trial design which can materially influence the results. For example, in the majority of sow feeding experiments in which differing protein levels have been compared this has been accomplished by varying the proportion of protein supplement to cereal in the diet, which results in a confounding of the effect of protein level with that of protein quality. In addition, diets may or may not be of equal energy content. In some diets amino acids are supplied in protein-bound form; in others in synthetic form. The availability and the utilisation of individual amino acids may differ in the two cases. Other experimental variables include the level of body reserves possessed by the animals at the start of the experiment, length of lactation period, whether or not litter size is standardised shortly after birth, sow feeding method (controlled or ad. lib.), whether or not creep feed is provided for the litter, and a host of other environmental and genetic factors. Even when the same experiment is conducted at different centres it is usual for significant between-centre differences to occur in respect of many parameters (e.g. Mahan and Grifo 1975; Greenhalgh et al. 1977). Fortunately, treatment x centre interactions are less frequent.

In short, in assessing the significance and applicability of findings from a given experiment it is important to bear in mind the many pertinent features which can influence the results.

III. PROTEIN AND AMINO ACID REQUIREMENTS OF SOWS

(a) Gestation

The daily protein requirements of pregnant gilts and sows were estimated by the Agricultural Research Council (ARC 1967) to be 250 g crude protein (CP) for the first 11 weeks of gestation rising to 400 g CP for the final two weeks. These values, which were based primarily on nitrogen balance data, were stated to include adequate safety margins which, for late pregnancy, could be excessive. In the United States, the National Research Council (NRC 1973) maintained its earlier recommendation (NRC 1968) of a daily intake of 280 g CP for both pregnant gilts and sows (see Table 2) - a figure which is almost identical to the ARC estimate when the latter is converted to an average value for the entire gestation period.

One of the main developments since the late 1960's has been a concensus of reports indicating that these levels are, indeed excessive. However, the extent to which current recommendations can be reduced depends upon which criteria are used. As indicated in a number of reviews, including those by Elsley and MacPherson (1972) and Pond (1973), there are large differences in the relative sensitivity of the various components of performance to protein insufficiency.' The general trend is shown in Table 1.

Table 1. Relative sensitivity of various reproductive traits to reduced protein intake by the sow

Trait	Sensitivity
Sow weight	High
Milk production Litter weight gain	↓
Piglet survival	↓
litter weight at birth	↓
Litter size at birth	↓
Interval weaning to mating Conception rate	Low

It is apparent that as protein intake is reduced maternal weight, followed by litter weight (or gain) at weaning, are the first traits to be affected. However their value as practical indices of protein adequacy is not clear. Weight gain in sows during gestation is usually positively correlated with weight loss during lactation (e.g. O'Grady and Hanrahan 1975; Greenhalgh et al. 1977); so that a reduction of weight gain during gestation may have little or no effect on sow weight at the end of lactation. Again, litter weight at weaning is affected much more by feeding during lactation than by gestational diet; so that the relative influence of the latter is likely to be affected by the length of the lactation period. Increased intake of creep feed by piglets may also compensate for reduction in milk intake, especially after three weeks of age.

The feeding of all-cereal gestation diets (containing approximately 8 - 11.5% CP and fortified with minerals and vitamins) has generally resulted in some loss in litter performance compared with that achieved when a protein supplement was included.

All-maize gestation diets, which have been shown by Allee and Baker (1970) to be limiting in both lysine and tryptophan, have resulted in lower litter weights at weaning (Hesby et al. 1970; Hawton and Meade 1971) and, sometimes, to fewer pigs weaned (Baker et al. 1970a), Supplementation with 16% soyabean meal during the last five weeks of gestation has proved satisfactory (Baker et al. 1970b). Including 1.4% soyabean meal (Mahan and Mangan 1975) or 3.6% soyabean meal (Wahlstrom and Libal 1977) throughout gestation allowed gilts to produce as large and as heavy litters at birth as when diets containing conventional levels of soyabean meal were fed. The latter levels of protein provided not more than 70% of the daily intakes of protein recommended by the NRC (1973). However, uncertainty remains as to the effect of those lower protein intakes on milk production and composition in early lactation.

Barley has a higher content of essential amino acids, especially of lysine, than maize. Nevertheless, Canadian workers (Young, Forshaw and Smith 1973) found that gilts fed an all-barley diet (11.5% CP) produced pigs with lower birth and weaning weights than those fed a similar diet supplemented with 9 - 12% soyabean meal. Greenhalgh et al. (1977) found that an all-barley diet (9.4% CP and 0.31% estimated lysine) had some adverse effect on litter size at birth. A diet containing barley supplemented with 4.8% of a 1:1 mixture of soyabean meal and fishmeal (11.5% CP and 0.46% estimated lysine) proved satisfactory.

It is unfortunate that in the majority of sow feeding experiments the dietary content of amino acids, particularly of those likely to be limiting, was not determined. Variation in protein quality between diets used by different workers has contributed to variation in estimates of protein requirements. Supplementation of cereal-based diets is essentially a matter of raising the level of the appropriate limiting amino acids to meet animal requirements, using either conventional protein concentrates or the requisite synthetic amino acids.

Table 2. Protein and amino acid requirements of sows and gilts as estimated by the National Research Council (1973)

	Percentage or amount per kilogram of diet		Amounts per day (g)		
	Bred gilts (110-160 kg) Bred sows (160-250 kg)	Lact. gilts (140-200 kg) Lact. sows (200-250 kg)	Bred gilts & sows	Lact. gilts	Lact. sows
Feed intake kg			2.0	5.0	5.5
Protein	14	15	280	750	825
		†		†	†
Arginine		0.34		17.0	18.7
Histidine	0.2*	0.26	4.0*	13.0	14.3
Isoleucine	0.37	0.67	7.4	33.5	36.9
Leucine	0.66*	0.99	13.2*	46.4	51.0
Lysine	0.42	0.60	8.4	30.0	33.0
Methionine + cystine	0.28	0.36	5.6	18.0	19.8
Phenylalanine + tyrosine	0.52*	1.00	10.4*	46.9	51.6
Threonine	0.34	0.51	6.8	25.5	28.1
Tryptophan	0.07	0.13	1.4	6.5	7.2
Valine	0.46	0.68	9.2	34.0	37.4

* level adequate

† based on requirements for maintenance plus amino acids produced in milk when sows fed 5 - 5.5 kg feed/d and amino acids assumed to be 80% available.

An example of the extent to which protein level is reducible when protein of high quality is fed is provided by Elsley, MacPherson and McDonald (1971). Over three parities, a gestation diet containing only 7% CP (142 g CP intake per day) resulted in comparable litter performance (in terms of number and weight of pigs born and reared to six weeks, and piglet composition at birth) to that achieved by litters whose dams were fed gestation diets containing 10 or 13% CP

Based on nitrogen balance data, the NRC (1973) amended its earlier (1968) estimate of the lysine requirements of pregnant gilts and sows from 0.49 to 0.42% of the diet, or a daily intake of 8.4 g lysine (Table 2). Duée and Rérat (1975) reported that a gestation diet for gilts which met this NRC (1.973) recommendation and which included 0.2% synthetic lysine resulted in as large and as heavy litters at birth as a diet of similar protein content (10.5%) but containing a further 0.2% lysine (giving a total of 0.63% lysine). Although all animals were fed a generous level of protein during lactation, the latter diet resulted in greater piglet weight gains up to three weeks of age (4.09 v. 3.41 kg ; P<. 01).

In summary, it appears that there is scope to reduce protein intake during pregnancy below currently recommended levels provided that daily lysine intake does not fall below the NRC (1973) figure. Whether lysine intake can be reduced even further depends upon the importance attached to the prevention of some decline in milk production and litter growth in early lactation. Further work is needed to elucidate the influence of protein and amino acid intake in late pregnancy on the output and composition of colostrum and milk in early lactation.

(b) Lactation

The ARC (1967) estimates of the protein requirements of lactating sows were calculated factorially assuming a gross efficiency of conversion of dietary protein to milk protein of 33%. For a sow suckling eight pigs over an eight-week lactation period the average daily protein requirement was estimated to be 1089 g. The NRC (1973) recommendations are substantially lower, (Table 2).

From experiments involving a six-week lactation period MacPherson, Elsley and Smart (1969) and O'Grady (1971) concluded that a daily protein intake of 700-750 g was adequate. Elsley and MacPherson (1972) also cite a Danish experiment (Nielsen 1968) giving very similar results. In the latter experiment there was only a small decrease in milk production and milk protein output, which did not affect piglet performance adversely, when the dietary protein level of suckling sows was reduced from 16 to 13%.

O'Grady and Hanrahan (1975) used a total of 96 animals to study the effects, over four parities, of supplementing an all-barley diet (9.3% CP) with either (i) soyabean meal, (ii) lysine, (iii) methionine, or (iv) a mixture of soyabean meal, lysine and methionine, during a 5-week lactation period.

Sow feed intake was slightly depressed on the all-barley diet. sow weight loss during lactation was decreased by feeding up to 11.8% CP and 0.78% lysine. However, as a result of compensatory weight gains during pregnancy, when protein levels were generous, treatment differences in sow weights at the end of the fourth lactation were not significant. Litter and piglet weight gains did not respond to diets containing more than 9.3% CP and 0.58% lysine (providing daily lysine intakes of 26 and 33 g for first and subsequent lactations respectively. There was no response to the methionine supplement, indicating that the all-barley diet, containing 0.39% sulphur amino acids, was adequate in this regard. These findings are in general agreement with the NRC (1973) recommendations for lysine and for methionine + cystine but not for protein.

Using a basal diet consisting of maize and which provided all essential amino acids except lysine, Lewis and Speer (1973) studied the effect, during the first three weeks of lactation, of incremental additions of lysine on nitrogen retention and balance, milk production and composition, piglet weight gains, changes in sow weight and backfat thickness, and plasma free essential amino acids and urea. As estimated from the intercept of two linear regressions fitted to the data for the various parameters, it was concluded that lactating sows consuming 5.5 kg of feed (75 MJ ME) per day required a minimum of 0.53 - 0.56% lysine (equivalent to a daily intake of approximately 30 g lysine).

As assessed by changes in levels of plasma free lysine and blood urea when graded levels of lysine were added to a diet of barley, Sohail, Cole and Lewis (1974) concluded that a daily intake of 38.4 g lysine was probably in excess of requirements.

(c) Carry-over effects between gestation and lactation

Bearing in mind the sow's proven ability to accumulate and to mobilise tissue reserves as the need arises it is unrealistic to consider protein requirements during one stage of the gestation/lactation cycle without reference to protein intake in the other.

Comparatively few experiments have been reported in which the relationship between protein intakes during pregnancy and lactation has been studied. Earlier, Elsley, MacPherson and McDonald (1971) in an experiment in which protein quality was held constant, failed to find any interaction between protein intake during gestation with that during lactation.

More recently, however, a number of studies have been reported in which interrelationships between protein levels during pregnancy and lactation were found. Mahan and Mangan (1975) reported responses to increase in protein level during gestation, in terms of sow feed intake and litter weight gains when a 12% CP lactation diet was fed but not when the lactation diet contained 18% CP. The Ohio workers (Mangan and Grifo 1975) have also suggested that, as assessed by milk production and litter growth, the amino acid requirements of lactating gilts which are fed an all-maize diet during pregnancy may be greater than for gilts which are fed gestation diets of higher protein content. However, over three parities, a high protein (20%) lactation diet failed to prevent smaller weight gains in early lactation (attributed to poorer milk production at this stage) in litters of sows fed an all-maize gestation diet, in comparison with the gains of litters from sows fed a soyabean meal - supplemented diet (14% CP) during pregnancy and a 15% CP lactation diet (Mahan 1977). In the early stages of the third parity there was a serious agalactia problem which was restricted to sows fed the all-maize gestation diet.

Similar findings to those of Mahan and Mangan (1975) have been reported by Greenhalgh et al. (1977). In a large co-ordinated experiment involving a total of 468 litters at seven centres and covering 3 - 5 parities, the effects were examined of four levels (9, 11, 13 and 15%) of protein during gestation each in combination with two protein levels (13 and 17%) during lactation. As in the Ohio experiments, protein quality varied with protein quantity. At the higher lactation protein level, litter weight at weaning' (at six weeks) was unaffected by protein level during gestation. However, at the lower protein level during lactation (13% CP) response to pregnancy level of protein was curvilinear, that is, litter weights at weaning were smallest and greatest when the pregnancy protein levels were 9 and 13% respectively. It was concluded that the lowest satisfactory combination was the "11%" level (actually 11.5% CP) during pregnancy and the "13%" level (actually 13.5% CP) during lactation. These levels correspond to daily intakes of 230 g CP and 9.2 g estimated lysine during pregnancy, and approximately 770 g CP and 34 g estimated lysine during lactation.

A difference in the respective lactational requirements of first-litter and older sows was reported by Duée (1976). He found that in primiparous animals a 13% CP lactation diet was adequate for litter gain provided the gestation diet contained 13% CP at least from the 75th day of pregnancy. However, in older sows a 13% CP lactation diet depressed litter gain, relative to that of progeny of sows fed a 16% CP lactation diet, irrespective of protein level during gestation.

IV. CONCLUSIONS

The potential for reduction in the protein content of sow diets depends upon the relative importance ascribed to the several criteria of reproductive performance. It is generally agreed that sow weight, followed by litter weight gain, are the first traits to be affected as dietary protein level is reduced. In both cases, however, compensatory effects may ensue, so that in the longer term the initial adverse effect may be of little or no consequence. Moreover, cognizance must be taken of the implications of changes in management practice. In particular, many of the experiments quoted involved a six-week lactation period. With the trend to earlier weaning (at 3-4 weeks), absolute weight losses in sows during lactation are likely to be less; which may mean that a lactation diet of lower protein content may be satisfactory. Conversely, with earlier weaning, milk production during the first three weeks post partum assumes greater relative importance.

In view of the sensitivity of sow weight to dietary protein, Elsley (1976) has suggested the use of net gain in sow weight per gestation/lactation cycle in relation to an appropriate "target" value as a simple method of monitoring protein adequacy. However, it is difficult to see how this approach can differentiate between the respective effects of level of feeding (involving energy intake) and protein intake.

The available evidence suggests that if sow diets are formulated to meet NRC (1973) requirements for amino acids, especially lysine, rather than for protein this would allow a marked saving in the use of protein supplements. At current prices, and depending upon what assumptions are made with respect to efficiency of utilisation, the use of synthetic lysine to partially, or even completely, replace protein concentrates in supplementing diets based on barley or wheat may be indicated. On the other hand, there is some evidence that all-cereal diets during pregnancy may adversely affect piglet survival, partly as a result of impairment of milk production in early lactation. As the level of protein intake in lactation is reduced it appears that protein intake during gestation becomes more critical.

In view of variation in commercial practice in levels of sow feeding, statement of the protein and amino acid requirements in terms of quantities per day is preferable to specifying dietary concentrations.

Greater emphasis in the formulation of diets on meeting requirements for amino acids rather than for protein focusses attention on the need for more information on the available amino acid content of feeds and on the efficiency of utilisation of synthetic lysine.

Few attempts have yet been made to formulate sow rations with the aim of maximising economic returns rather than maintaining "normal" performance. In the absence of economic analyses of response functions relating protein intake to various reproductive criteria it is suggested that dietary protein intakes should be such as to prevent reduction in litter size at birth or the impairment of production of colostrum.

As yet no research has been reported in this country to indicate the extent to which local conditions may require modification of overseas findings in respect of the protein intake of sows. For this reason and because of variability in the level and quality of protein within feeds any reduction in protein allowances below those currently recommended should be made tentatively and with due realisation of the uncertainties involved.

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