# NITROGEN METABOLISM IN THE YOUNG SOW

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## SUMMARY

The establishment of quantitative relationships between nitrogen (N) retention and energy and protein intake in breeding animals is essential to enable producers to determine the consequences of altering nutrient intake on changes in body composition, reproductive efficiency and lactational performance. Results of an experiment with pregnant gilts revealed that maximum rates of N retention occurred at 0.58, 0.55 and 0.66 g lysine/MJ DE during early, mid- and late pregnancy respectively. Furthermore, the relationship between N retention and energy intake was linear over the range in dietary energy intakes normally encountered in commercial pig production. Results of a lactation study emphasised the need to relate nutrient requirements of the lactating sow to the production levels attained by the sow. Sows required a diet containing 0.85g lysine/MJ DE during their first lactation to maximise N conservation. However, maximum lactational performance appeared to occur at lower levels of dietary protein.

## INTRODUCTION

The recommended daily lysine requirements of sows during pregnancy and lactation are 8.6 and 33 g respectively (ARC 1981). However, there is considerable variation in the estimates of lysine requirements made by different workers. For example, estimates of the requirements for lysine during lactation range from 20 g/day (Boomgardt et al. 1972) to about 50 g/day (Stahly et al. 1990). The variation in estimated lysine requirements may exist because of different methods and techniques used to estimate lysine requirements. Furthermore, the requirement will vary with different levels of production, at different stages of production and with the different genotype that is now apparent in commercial pig herds.

Considerable information on the response of pregnant and lactating sows to levels, quality and sources of protein has been provided from empirical and production type experiments As low dietary protein intakes and/or diminished tissue protein reserves can adversely affect both fertility and lactational performance of young sows, it seems appropriate to develop feeding strategies for the gilt and young sow that optimise tissue protein deposition to ensure that satisfactory breeding performance of the modern young sow is maintained.

The aim of this project was to investigate the response of sows to lysine and energy intakes. Relationships between protein deposition and energy and protein intakes have been established for grower/finisher pigs. Similar relationships have yet to be determined for pregnant and lactating sows. The establishment of these quantitative relationships is essential to enable producers to determine the consequences of altering nutrient intake. Likely changes in bodyweight and composition in response to energy and protein intake can also be estimated. Furthermore, the information obtained from this project can be incorporated into the sow/reproduction portion of the AUSPIG growth model.

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## MATERIALS AND METHODS

Experiments were designed to determine the response of pregnant gilts and lactating first-litter sows to lysine intake and energy intake. N retention was the major parameter used to estimate lysine requirements and the response of animals to energy intake. Important production traits such as bodyweight and fat level of the sow, milk production, litter growth rate and fertility of the sow were also recorded.

### Animals and Treatments

Experiment 1 Thirty-two female pigs were allocated at mating among eight dietary protein treatments. The experimental diets were formulated to contain similar amounts of digestible energy (DE) but with crude protein (CP) concentrations ranging from 50 to 235 g/kg. The balance of essential amino acids contained in the diet of highest protein concentration was designed to conform as closely as possible to that of the ideal dietary protein (ARC, 1981). The highest protein diet contained 470.9 g/kg wheat, 189.3 g/kg skim milk powder, 284.0 g/kg soyabean meal, 30.0 g/kg fat blend and 0.5 g/kg DL-methionine with the balance being minerals and vitamins. The amino acid balance was maintained in the lower protein diets by dilution with starch and sugar. All diets were offered throughout pregnancy at the rate of 1400 g per animal daily.

Experiment 2 Thirty gilts were allocated at mating to six rates of feeding ranging from 1.1 to 3.1 kg/d. These intakes were provided by a single diet which contained 773.1 g/kg wheat, 140.9 g/kg soybean meal 30.0 g/kg blood meal, 20.0 g/kg fat blend, 0.9 g/kg DL-methionine and 2.5 g/kg L-lysine with the balance being minerals and vitamins. The diet was formulated to contain approximately 14.6 MJ DE/kg and 10.7 g/kg lysine which would be slightly in excess of that required to promote maximum rates of N retention in Exp.1. Under these conditions of dietary protein adequacy, the effect of feeding level was synonymous with an effect of energy intake on N retention.

Experiment 3 Thirty-six female pigs were allocated at their first parturition among six dietary protein treatments The experimental diets (Table 2) were formulated to contain similar amounts of DE but with CP and lysine concentrations ranging from 63 to 238 g/kg and from 4.4 to 15.1 g/kg, respectively. The ratio of other essential amino acids to lysine were in excess of the ratios suggested by Dourmad et al. (1991), which were based upon the amino acid requirements for maintenance and the amino acid composition of milk from high producing sows The highest protein diet contained 509.4 g/kg wheat, 149.2 g/kg skim milk powder, 250.0 g/kg soyabean meal, 30.0 g/kg blood meal, 30.0 g/kg fat blend and 0.9 g/kg DL-methionine with the balance being minerals and vitamins. The amino acid balance was maintained in lower protein diets by dilution with starch and sugar Sows were given 2.0 kg of the respective lactation diet on the day of parturition and this increased by 0.5 kg/d to a maximum of 4.0 kg/d which was maintained throughout the remainder of the lactation period.

### Nitrogen Balance studies

Nitrogen balance studies were conducted during early (day 30) mid (day 60) and late (day 90) pregnancy or during early (day 10) and late (day 24) lactation.

For at least 12 d before and during each collection period, gilts in Exp.2 were given the appropriate experimental rate of feeding. However, between N balance periods, gilts were offered various levels of feeding that promoted different body weight gains to ensure that live weights of pigs at the beginning of each collection period were similar among treatments and would not confound the treatment effects of energy intake.

During each 5-day collection period, urine was collected daily via Foley bladder catheters into sulphuric acid and 10% samples were taken. Frozen daily samples were bulked for each pig at the end of each collection period. A grab sample of faeces was also collected daily throughout each collection period and subsequently mixed, subsampled and freeze-dried. Urine, faeces and diet samples were analyzed for Kjeldahl nitrogen by standard procedures (AOAC 1975) and chromic oxide concentration of faeces and diet samples was determined using the x-ray fluorescence spectrometry (Norrish and Chappell 1977).

In Experiment 3, milk yield of sows during each collection period was calculated from milk intakes of individual pigs as estimated from their water turnover, determined by dilution of injected deuterium oxide ($D_2O$) (Pettigrew et al. 1987). Milk samples (2 to 5 ml) were collected from three to six glands on each sow during the first suckling bout immediately after the pigs had been returned to the sow at the beginning of each measurement period. Samples were immediately immersed in liquid nitrogen and subsequently stored at -20°C until analyzed further The concentration of protein, fat and lactose in milk samples was determined by the methods described by Atwood and Hartmann (1992).

## General Husbandrv

In Experiments 1 and 2, all pigs were housed in individual stalls in an insulated building in which the minimum temperature was maintained at 18°C. Live weight and ultrasonic backfat depth of each gilt were recorded at mating, early, mid- and late pregnancy and after farrowing. Backfat depth was measured 45mm from the midline at the level of the last rib ($P_1$). The mean (±SE) age, live weight and backfat depth of gilts at mating were 209.6 (1.5) d, 99.7 (1.2) kg and 21.2 (.5) mm and 203.0 (1.6) d, 102.5 (1.3) kg and 19.5 (.4) mm in Expts. 1 and 2, respectively.

In Experiment 3, all pigs were housed in farrowing crates in an insulated but unheated building in which the minimum temperature was in excess of 16°C. Live weight and ultrasonic backfat depth of each sow were recorded at mating, before farrowing, 1 d after farrowing, early and late lactation and weaning. Litter size was standardized to nine pigs per litter by fostering pigs within a few days of parturition. Pigs had no access to creep feed or water throughout lactation and litters were weaned at the **completion** of the second N balance period.

# RESULTS

## Experiment 1

The response of N retention to dietary protein was described by a two-phase linear regression model comprising an ascending linear component that was dependent on dietary protein and a horizontal component representing maximum N retention at the higher levels of dietary protein (Figure 1).

The corresponding maximum rates of N retention were 10.0, 12.1 and 16.5 g/d, respectively. Estimated from the intercept of the two regression lines at each stage of pregnancy, maximum N retention during early, mid- and late pregnancy occurred at 0.58, 0.55 and 0.66 g lysine/MJ DE, respectively.

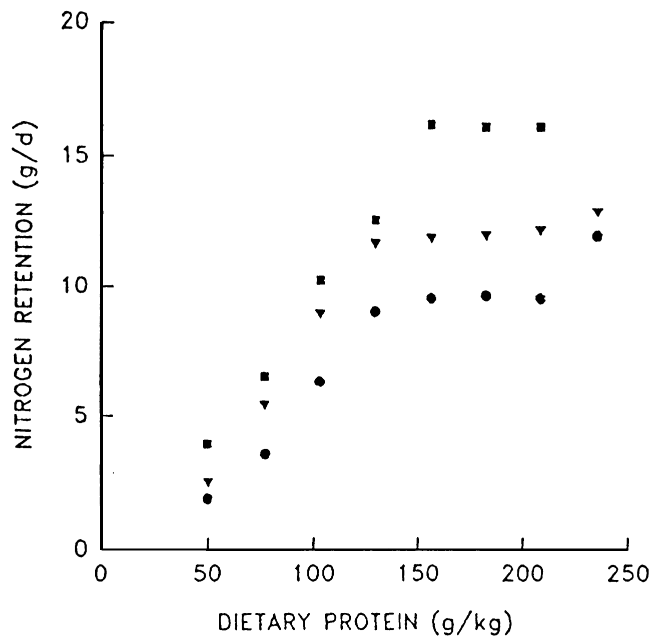


Figure 1 The response of gilts to dietary protein content during early (●), mid- (▼) and late (■) pregnancy

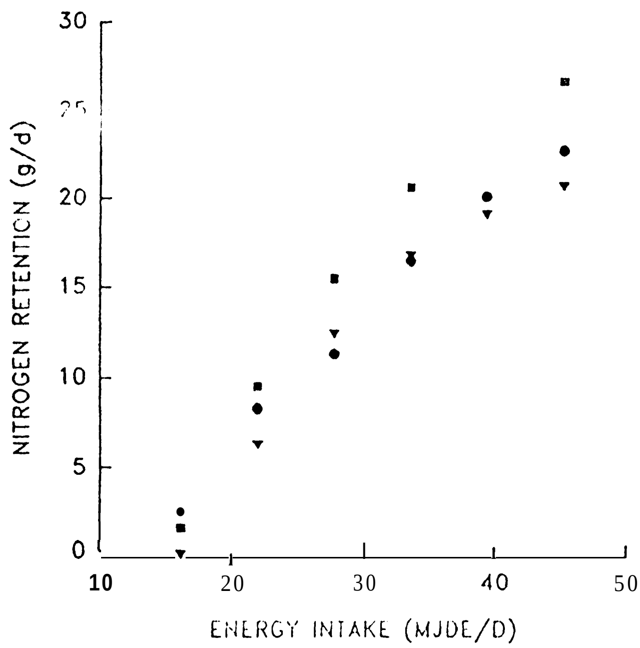


Figure 2 The response of gilts to dietary energy intake during early (●) mid- (▼) and late (■) pregnancy

Experiment 2

There were significant linear and quadratic relationships between N retention and energy intake (Figure 2). The quadratic equations describing the relationships between N retention and DE intake accounted for more of the variation in N retention than the respective linear equations at each stage of pregnancy (Table 1). Extrapolation of the quadratic relationships revealed that zero N retention occurred at daily energy intakes of 13.3, 15.9 and 14.9 MJ DE during early, mid- and late pregnancy respectively.

TABLE 1 Equations relating nitrogen retention (g/d) to digestible energy (DE) intake (MJ/d) during early, mid- and late pregnancy

| Item | Coefficients | | | $R^2$ | Residual standard deviation |
|---|---|---|---|---|---|
| | Constant | DE | $DE^2$ | | |
| Linear | | | | | |
| Early pregnancy | -7.68 | .693 | | .987 | .96 |
| Mid-pregnancy | -8.84 | .701 | | .948 | 2.01 |
| Late pregnancy | -9.71 | .847 | | .963 | 2.04 |
| Quadratic | | | | | |
| Early pregnancy | -13.86 | 1.142 | -.007 | .995 | .68 |
| Mid-pregnancy | -24.80 | 1.861 | -.019 | .998 | .46 |
| Late pregnancy | -26.17 | 2.044 | -.020 | .999 | .23 |

## Experiment 3

During both periods of lactation, there were significant positive linear relationships between the level of dietary protein and milk yield, content of fat and total solids in milk. Milk yield increased from 7.79 to 9.19 kg/day and from 7.02 to 8.90 kg/day while total solids in milk increased from 199 to 225 g/kg and from 202 to 228 g/kg during early and late lactation respectively, in response to increasing the level of dietary protein from 63 to 238 g/kg CP. Nitrogen balance seemed to plateau at the higher levels of dietary protein because there was no significant increase in N balance as dietary CP increased from 203 to 238 g/kg (Figure 3). Consequently the response of N balance to dietary protein may be described by a two-phase linear regression model made up of an ascending linear portion and a horizontal component representing maximum N balance which is dependant upon

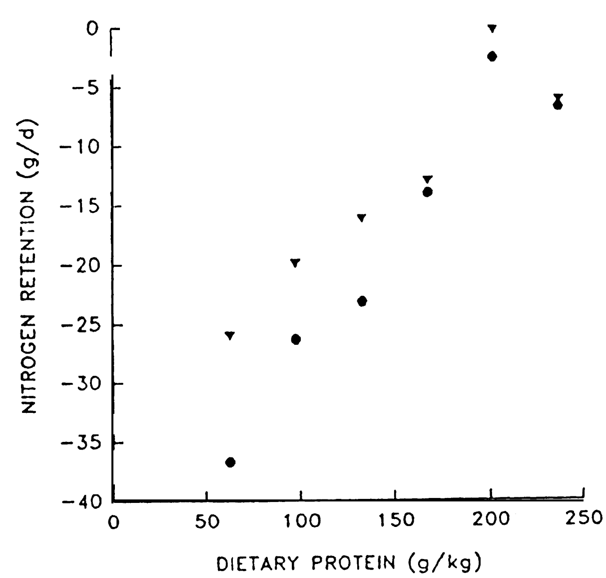


Figure 3 The response of firs t-litter sows to dietary protein con tent during early (●) and late (▼) lactation

available energy. The maximum rates of N balance during early and late lactation were -4.6 and -3.5 g/d respectively. Based upon the intercept of the two regression lines, maximum N balance occurred at 0.85 g lysine/MJ DE at both stages of lactation. Lactational performance criteria appeared to reach maximum levels at lower concentration of dietary protein (between 133 and 168 g CP/kg) (Table 2).

TABLE 2 The effects of dietary protein concentration on the lactational performance of first-litter sows

| | Dietary protein, g/kg | | | | | | |
|---|---|---|---|---|---|---|---|
| | 63 | 98 | 133 | 168 | 203 | 238 | SEM |
| Piglet pre-weaning growth rate (g/d) | 179 | 193 | 2.5 | 228 | 213 | 216 | 9 |
| Early lactation | | | | | | | |
| milk yield (kg/d) | 7.79 | 8.02 | 9.12 | 8.89 | 8.39 | 9.19 | .35 |
| milk protein (g/kg) | 48 | 47 | 48 | 50 | 50 | 51 | 2 |
| milk fat (g/kg) | 75 | 93 | 110 | 105 | 103 | 101 | 6 |
| milk solids (g/kg) | 199 | 215 | 231 | 228 | 226 | 225 | 7 |
| Late lactation | | | | | | | |
| milk yield (kg/d) | 7.02 | 7.40 | 8.42 | 8.40 | 7.76 | 8.90 | .35 |
| milk protein (g/kg) | 47 | 50 | 50 | 55 | 56 | 54 | 2 |
| milk fat (g/kg) | 80 | 89 | 106 | 110 | 105 | 101 | 7 |
| milk solids (g/kg) | 202 | 214 | 230 | 238 | 236 | 228 | 7 |

## DISCUSSION

The results of Experiment 1 demonstrated the typical dose response to increasing dietary protein levels that has been reported for N or protein accretion in growing pigs (Black et al., 1986). The dietary concentrations of protein required to support maximum N retention in pregnant gilts fed 1.4 kg/d were 142,133 and 162 g/kg during early, mid-and late pregnancy, respectively. The corresponding dietary lysine: DE values were 0.58, 0.55 and 0.66 g lysine/MJ DE. Our estimates of dietary requirements for maximum N retention in pregnant gilts are similar to those reported by ARC (1981) and SCA (1987) for finisher pigs between 50 and 90 kg live weight, being 0.60 and 0.65 g lysine/MJ DE, respectively. There is increasing evidence of a plateau relationship between the potential rate of protein deposition in pigs and live weight; similar levels of N retention occur over a wide weight range of between 50 and 130 kg live weight (Whittemore et al., 1988). Thus, it is likely that the dietary requirements for maximum N retention for the pregnant gilt of between 100 and 135 kg live weight are similar to those of the finisher gilt.

The rate of N retention responded to the change in energy intake either linearly in early pregnancy and in a quadratic manner in later pregnancy. Willis and Maxwell (1984) also observed that N retention increased in pregnant gilts as daily energy intake was raised from 26 to 30 MJ DE. In experiments in which energy intake has been increased independently of protein intake, several authors have also reported a linear relationship between N retention and DE intake for pregnant gilts (Etienne and Henry 1973; Etienne 1991). In these experiments, daily protein intake was maintained at between 275 and 408g CP, which could be considered adequate. The results of the experiments previously described in which the respective authors had examined the response of pregnant gilts to increasing energy intake up to 37 MJ of DE/d, have failed to provide any evidence of the linear/plateau form that has been suggested for pregnant gilts (Williams et al. 1985). The stronger quadratic relationships which occurred, particularly in late pregnancy suggest that a plateau may have been reached at higher energy intakes than we examined in our study. However, under most practical feeding strategies for pregnant gilts, daily energy intake is not likely to exceed 37 MJ DE and, consequently the concept of a constant dietary protein: energy ratio to maximize tissue protein accretion would remain valid in diet formulation for pregnant gilts.

The results of Experiment 3 show that lactating sows have the capacity to utilize dietary protein at levels up to 202 g of CP/kg in a diet containing 15 MJ DE/kg when offered at 3.8 kg/d during both early and late lactation. The corresponding dietary requirements for lysine during both early and late lactation would be 0.85 g lysine/MJ DE or 48.1 g/d. Our estimates of the requirements for protein and lysine are considerably higher than those recommended by ARC (1981) and NRC (1988) but are similar to more recent estimates of dietary protein and lysine requirements to maximise the lactation performance of modern sows (Stahly et al. 1990; Johnston et al. 4991). Associated with those higher dietary protein requirements were high litter growth rates. Using a conversion ratio of milk into pig gain of 3.8 g/g (Noblet and Etienne 1986) the estimated milk yield of sows in the studies of Stahly et al. (1990) and Johnston et al. (1991) were 7.9 and 8.4 kg/d, respectively which are considerably higher than those used by ARC (1981) and NRC (1988) to calculate dietary requirements. Thus, the protein and lysine requirements of lactating sows should be related to the potential lactational performance of the sow.

The amount of body tissue reserves and the ability of the sow to utilize these reserves to support milk production and maintenance may also complicate the assessment of the nutrient requirements of lactating sows. The other major factor likely to further influence the protein and lysine requirements of sows during lactation is energy intake. Although the fat reserves of sows at parturition were considerable and daily dietary energy intake was in excess of 56 MJ DE, energy may have still been limiting the lactational performance and N balance of sows in our study. Future studies should examine the influences of dietary energy intake and body reserves on lactational and N balance response of sows to dietary protein level.

Experiment 3 was designed primarily to establish quantitative relationships between N balance and dietary protein level and to establish protein and lysine requirements for lactating sows. Although the number of replicates were limited to fully evaluate production criteria, lactational performance seemed to plateau at lower dietary protein levels than those required to maximize N balance. Significant curvilinear responses to increasing dietary protein were evident for preweaning growth rate and fat and total solids contents of milk samples collected in early lactation. Furthermore, milk fat and total solids contents in late lactation together with milk yields at both stages of lactation also tended to plateau at the higher levels of dietary protein. The break-point in response of most criteria of lactational performance appeared to occur at between 133 and 168 g CP/kg.

These experiments established quantitative relationships between N balance and nutrient intake for the gilt during pregnancy and lactation. The practical significance of the studies with pregnant gilts are that firstly, the dietary protein and amino acid requirements of modern pregnant gilts will be similar to that for finisher pigs Secondly, the formulation of diets for pregnant gilts should be on the basis of optimum protein : energy ratio (rather than daily requirement) if maximum protein deposition is the criterion for performance. Finally, the protein and amino acid requirements for lactating sows will depend upon level of milk production, body condition, genotype and energy intake.

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