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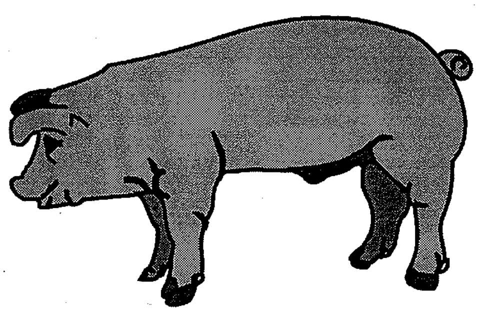

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Amino Acid Requirements in Lactating Sows: A Review.

1. Introduction.
The metabolism of amino acids in lactating sows is not as well understood as it is in growing pigs, and the area is currently surrounded by some controversy. Historically, amino acid requirements for lactation have been derived from studies based on the empirical approach in which one or more response variables are related to different dietary inputs. The recommendations obtained by this procedure may be representative only under the experimental conditions under which they have been undertaken. *"Extrapolation to other production conditions that differ with regard to environment, management, animal factors or intensity of production is ambiguous"* (Noblet et al., 1990). Another difficulty to overcome in assessing amino acid requirements for lactating sows is the choice of response variable. In most studies, daily milk yield or litter weight gain have been the preferred response criteria. However, lactation induces a strong homeorhetic drive for directing nutrients towards milk production (Baumann and Currie, 1980), which usually results in a certain degree of mobilization of body amino acids in order to support milk production. Maximum response in terms of milk production and litter weight gain can, therefore, be achieved even in situations where the diet does not provide optimum levels of nutrients. However, the effect of body mobilization on subsequent reproductive performance has usually not been taken into account when amino acid requirements have been derived. However, recent data suggest that the amino acid requirement for optimal reproductive performance in terms of weaning to estrus interval, farrowing rate and litter size is considerably higher than the requirement for maximal milk production (Wilson et al., 1996). The importance of dietary regiments on reproductive performance may become more pronounced in the future as the industry moves toward very early weaning.

It may be possible to overcome some of the limitations of the use of empirically obtained data for assessing amino acid requirements by doing factorial calculations to describe the dietary needs for the lactating sow. By doing so, the specific needs for important body functions have to be described and quantified. It should be possible to determine estimates of nutrient requirements this way. (Noblet et al., 1990, Pettigrew et al., 1993a). In the following review, an attempt to calculate amino acid requirements during lactation using estimates for various body functions is made.

2. Assumptions for factorial calculations
In order to calculate the amino acid requirement during lactation, several assumptions have to be made. A brief discussion follows.

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2.1. Maintenance requirement

Values for amino acid requirements for maintenance in lactating sows are not easily obtained, and we are unaware of any studies where such data have been obtained using modern genotypes at high production levels. Only data from other species (Owens et al., 1985, Owens and Pettigrew, 1989) or data obtained with growing pigs (Fuller et al., 1989) or non-lactating sows (Baker et al. 1966a,b,c, Baker and Allee, 1970) are available. However, given the relatively low requirement for maintenance during lactation compared to the requirement for milk production, small mistakes in these values will not have a great impact on the overall amino acid requirement. Pettigrew (1993) summarized maintenance requirements for growing pigs, rats and humans, and suggested these could be used for lactating sows with some modifications. In the following, these values are used, and the requirement for maintenance is considered being constant throughout lactation and independent of level of milk production.

2.2. Requirement for milk production

The lysine requirement for milk production has been estimated to be 26 g of lysine per kg of daily litter weight gain. (Pettigrew, 1993, Patience, 1994). The requirements for methionine, total sulphur containing amino acids (SAA), threonine and tryptophan were estimated as 26, 54, 66, and 18 % of that for lysine, respectively, by Etienne et al. (1993). Pettigrew (1993) agreed on the estimates for methionine and tryptophan, whereas he estimated the requirements for SAA and threonine at 45 and 58 % of lysine, respectively. It should be noted that these estimates are based on the assumption that all amino acids in milk are converted from plasma amino acids to milk protein amino acids with the same efficiency. In dairy cows, it has been shown that significant differences exist in the efficiency of converting plasma amino acids into blood amino acids (Bickerstaffe et al., 1974, Spires et al., 1975). Recent data indicate that also in lactating sows, the efficiency of utilization differs between amino acids (Trottier and Easter, 1995). Possible reasons for these differences might be that components other than free amino acids in plasma, e.g. albumin, GSH or dipeptides, might contribute to the production of milk protein amino acids (Atroshi et al., 1986, Blackwell et al., 1994), or that dispensable amino acids are synthesized from indispensable amino acids (Bequette et al., 1994). Also, protein turnover within the mammary gland has been shown to be considerable. Oddy et al, (1988) estimated that milk protein output represents only 40-60 % of total protein synthesis in the lactating mammary gland of goats. Based on these reports, it could be concluded that the assumption of equal efficiency of utilization of indispensable amino acids for milk production is probably not valid, but at this point, no data on the efficiency of utilization in the lactating mammary gland of sows under various dietary conditions are available. Hence, the mean values from the above mentioned estimates will be used in the following calculations.

2.2. Feed intake during lactation.

Sows given ad libitum access to feed do not eat the same amount of feed per day throughout lactation. Recent data from the University of Illinois suggest that first parity sows eating 4.5 kg per day on average during a 21 day lactation period will eat four kg per day during the first week of lactation, 4.5 kg per day during the second week, and five kg per day during the third week (Trottier, 1995, personal communication). A similar feed intake curve will be assumed in the following calculations.

2.4. Daily milk production

Several experiments have shown that sows nursing nine to ten piglets have an average daily milk production of eight to ten kg. (Noblet et al., 1990, Stahley et al., 1990, Etienne et al., 1993). Assuming it takes approximately four kg of milk to produce one kg of litter weight gain (Patience, 1994), this level of milk production would be sufficient to support 2 to 2.5 kg of litter weight gain per day. However, pigs do not have a constant weight gain throughout the nursing period, hence, the demand for milk is not the same throughout lactation. Patience (1994) estimated the growth during a three week lactation period to occur with 25% during the first week, 33% during the second week, and 42% during the third week. A similar partitioning of milk production can be assumed, since milk production is closely related to litter growth rate (Noblet and Etienne, 1987). Under these circumstances, it can be calculated that a litter gaining 2200 g per day on average during a 21 day lactation period, will have a daily growth rate of 1650 g during the first week, 2200 g during the second week, and 2750 g during the third week. The daily milk production necessary to support such a growth rate would be 6.6 kg, 8.8 kg, and 11 kg during weeks 1, 2, and 3, respectively.

2.5. Composition of body protein

If dietary amino acids do not meet the requirements, sows can react by mobilizing body protein and(or) by decreasing milk production. The composition of body protein in sows has not been estimated, but in several studies, the composition of body protein in growing pigs has been reported.

In table 1, the average amino acid composition of body protein of growing pigs from six different studies is shown. In the following discussion, these values will be used.

Table 1 Amino acid composition of body protein. Average of six studies.[1]

Amino Acid	g/kg body Protein	Ratio
Lysine	64.5	100
Methionine	19.65	30.5
Methionine + Cystine	31.2	48.4
Threonine	37.6	58.3
Tryptophan	7.7	11.9
Valine	44	68.5

[1]Moughan and Smith, (1987), Campbell et al. (1988), Batterham et al., (1990), Kemm et al., (1990), Kyriazakis and Emmans, (1993), Bikker et al., (1994a).

[2] Tryptophan values were reported in only 3 studies.

3. Total amino acid requirements during a 21 day lactation period.

Using the above assumptions, the total amino acid requirement for a 21 day lactation period can be calculated as shown in table 2.

Table 2. Amino acid requirements (g/day) for lactating sows producing an average of 8.8 kg of milk per day during a 21 day lactating period.

		Week 1		Week 2		Week 3	
	RMa*	RMi**	RTo***	RMi**	RTo***	RMa**	RTo***
Lysine	2.09	42.9	45.0	57.2	59.3	72.0	74.1
Methionine	0.48	11.1	11.6	14.8	15.3	18.6	19.1
Met+Cys	2.63	21.0	23.6	28.0	30.6	35.3	37.9
Threonine	1.76	26.6	28.4	35.5	37.2	44.7	46.5
Tryptophan	0.59	7.7	8.3	10.3	10.8	13.0	13.6
Valine	1.07	31.5	32.6	42.0	43.1	52.8	53.9

*.R equirement for maintenance. ** Requirement for milk production. *** Total requirement.

Due to the increase in litter weight gain and subsequently in milk production, a considerable increase in the requirement for amino acids occurs with the advance of lactation. It should be noted that the amino acid requirements listed in table 2 are total amino acids. Assuming a lysine content of 7.5 % in milk protein (Pettigrew, 1993), the figures in table 3 corresponds to an overall efficiency of incorporating dietary lysine into milk lysine of 70 %. In a recent experiment, the efficiency of converting dietary lysine into body lysine in growing pigs was estimated to be 74 % (Bikker et al. 1994b).

Assuming a feed intake pattern of 4, 4.5, and 5 kg per day during the first, second and third week of lactation, as described above, the total amino acid intake during each week of lactation obtained by feeding a 0.9 % lysine diet can be calculated as shown in table 3. If that same 0.9 % lysine diet is fortified with synthetic lysine, methionine, threonine and tryptophan to yield a 1.2 % lysine diet, the total daily intake of amino acids will increase to the levels shown in table 4.

Table 3. Amino acid intake during lactation from a 0.9 % lysine diet.

	Week 1		Week 2		Week 3	
	Intake	% of Req.	Intake	% of Req.	Intake	% of Req.
Lysine	36	80	40.5	68	45	61
Methionine	11	95	12.6	83	14	73
Met.+Cys	24	102	26.6	87	29.5	78
Threonine	26	91	29.7	80	33	71
Tryptophan	8	96	9	84	9.9	73

Valine	34	104	38	88	42.4	78.6

Table 4. Amino acid intake during lactation from a 1.2 % lysine diet.

	Week 1		Week 2		Week 3	
	Intake	% of Req.	Intake	% of Req.	Intake	% of Req.
Lysine	48	107	54	91	60	81
Methionine	14.4	124	16.2	106	18	94
Met.+Cys	26.4	112	30	98	33	87
Threonine	31	110	35	94	39	84
Tryptophan	10	120	11.3	105	12.5	92
Valine	34	104	38	88	42.4	78

It appears from table 3 that a 0.9% lysine diet does not provide sufficient levels of amino acids to support milk production. Breakdown of body protein will be necessary throughout lactation in order to provide enough amino acids for milk protein synthesis. It is also apparent that this diet does not provide amino acids on an ideal basis. This can be seen from the fact that not all amino acids are present as the same percentage of the requirement. Lysine is clearly the first limiting amino acid.

From table 4, it appears that the amino acid deficiency could be partially ameliorated by feeding the 1.2% lysine diet. During the first of lactation, all amino acids are present in excess of the requirement, during the second week some of the amino acids are present above the requirement, whereas all amino acids are deficient during the third week. Breakdown of body protein will occur during the second and third week, but at a lower rate than if the 0.9% diet was fed. Lysine and valine seems to be approximately equally deficient. The extent of body protein breakdown can be calculated by comparing the values in table 2 with those in table 3 and 4, respectively. Sows fed the 0.9% lysine diet will have a need for 9 g of lysine catabolized from body stores per day during the first week of lactation, calculated as the difference between the requirement (table 2) and the actual amount provided (table 2). With 6.45 g of lysine per 100 g of body protein (table 2), a total of 140 g of body protein needs to be catabolized daily during the first week of lactation. These 140 g of body protein also provides a total of 2.7 g of methionine, 5.25 g of threonine, and 1.1 g of tryptophan, which is also available for milk production. By adding these amounts to the amounts provided from the diet (table 3), it appears that all amino acids are now present at or above the requirement. Similar calculations reveal that the need for total lysine supplied from body protein is 19 g per day and 29 g per day during the second and third week of lactation, respectively. These amounts of lysine corresponds to 295 g and 450 g of protein broken down from body stores daily during week two and three of lactation. Therefore, a total of 6.195 kg of body protein is needed for milk protein synthesis during a 21 day lactation period under these circumstances. Doing the same type of calculations for the 1.2% lysine diet shows that only two kg of body protein needs to be mobilized in sows fed this diet. It should be kept in mind that the above calculations are based on an average daily feed intake of 4.5 kg. If sows were eating 6.5 kg of feed per day and fed the 0.9%

lysine diet, they would be in a negative lysine balance only during week three, and they would be fed excess lysine on the 1.2% diet throughout lactation.

4. Conclusion

The above calculations rely on a series of untested assumptions and interpretations of data from many different experiments with different genotypes, different management conditions and different production levels. For instance, the lysine requirement of 26 g per kg of litter weight gain was calculated by Pettigrew (1993) by comparing seven different experiments conducted over 20 years in Europe and the United States. However, the data presented are probably the "best guess" that can be derived from current knowledge. Two important conclusions can be derived from these data:

- **1.** The numbers in table 2, indicate that the need for amino acids in high producing lactating sows might be considerably higher than prescribed by current recommendations (NRC, 1988), if weight loss during lactation should be avoided, but they are in good agreement with the numbers estimated recently by Aherne (1995). If a close connection between loss of body protein during lactation and subsequent reproductive performance exist, as suggested by Wilson et al. (1996), the above data seems to indicate that higher amino acid levels need to be fed during lactation in order to improve reproductive performance. If sows are only eating 4-5 kg of feed per day, a very high amino acid concentration in the diet may be required in order to obtain optimal reproductive performance.The estimated amino acid requirements also exceed what has been estimated as the amino acid requirement in most empirical studies, i.e. by Stahley et al.(1990), Johnston et al. (1991) and Etienne et al. (1993). In these studies, the optimum daily intake of lysine was estimated at 45 to 50 g. Several reasons are likely to account for the difference between these studies and the above calculations. Firstly, in the studies mentioned, no attempt was made to differentiate the requirement between the first, second and third week of lactation. Secondly, the conclusions were based only on litter weight gain and daily milk yield, whereas subsequent reproductive performance was ignored. Thirdly, no attempt was made to differentiate between dietary lysine and lysine obtained from mobilized body stores; thus, it is likely that in addition to the estimates for dietary lysine, lysine from body stores have also been utilized by these sows.

- **2.** The above calculations are based on a summary of empirically obtained conclusions rather than real factorial calculations based on rates of efficiencies during various metabolic pathways. It is apparent that at present, it is not possible to estimate amino acid requirements based only on factorial calculations, because there is a lack of data to be used in such calculations. For instance, the calculations rely on the untested assumption that no obligatory changes in amino acid content of internal organs takes place during lactation. It may well be that such changes indeed occurs - e.g. in the liver, the uterus and(or) the mammary gland. However, at this point no information on these issues exist, and more research in the area is needed in order to fully understand the amino acid metabolism in lactating sows.

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