The benefits of low protein diets

by Sheila Heidi M. Ramos, Degussa (SEA) Pte Ltd, 3 International Business Park. 07-18 Nordic European Centre, Singapore 609927.

With intensified and technology based animal rearing systems, pig producers are continuously exerting extra effort to make production more efficient. Modern swine breeds are carefully selected for body weight gain or maximum lean tissue deposition. With these developments, defining the nutritional requirements from birth to market weight is very critical.

Numerous publications from government, private research institutions and commercial swine breeders worldwide resulted in individual nutritional recommendations for different growth stages aiming for pigs having lean carcases and faster growth rate.

Cost is another factor to consider when formulating swine feeds. Nutritionists are tasked to come up with raw material combinations in the right proportions to meet specific nutrient requirements at minimum dietary cost.

It is a common practice to set minimum requirements for protein, energy, minerals and amino acids in the formulations.

Usually it is protein that is cost limiting. Pigs do not have requirements for protein, but rather for appropriate level and balance of amino acids. Animal protein needs differ depending on their requirement for optimum performance.

Unbalanced amino acids will be used as an expensive nutrient source, degraded and subsequently excreted.

Excess protein is inevitable, especially when only synthetic lysine and methionine are available in the diet, while the requirements for the other amino acids are sourced from either the plant or animal protein bound sources. These excesses are excreted and eventually contribute to environmental pollution causing swine health related problems.

If minimum levels of crude protein (CP) are released, it is the amino acid requirements (lysine, methionine, threonine and tryptophan) that usually determine the crude protein level in the diet. With the availability of synthetic amino acids, formulations can now be done using low CP levels.

The majority of the main swine producing countries in Europe have successfully adopted the use of low protein concept in swine feed formulation. Researches have been conducted to show the benefits of using low protein levels in swine feed formulation.

National feed laws

Minimum levels are prescribed by national feed laws, which need to be complied with to pass the standards for commercial feeds. Specifications vary from one country to an other.

For example, in Thailand (Table 1), the minimum levels are specified for protein, metabolisable energy (ME), minerals and amino acid lysine and methionine + cystine.

CP levels of 17-18.5% for commercially available swine grower feeds, way above the minimum 16% specification is commonly found in the Thai feed market.

With this scenario, existing feed laws in the case of Thailand, the Philippines and Indonesia are not a concern in implementing low protein levels in swine feeds.

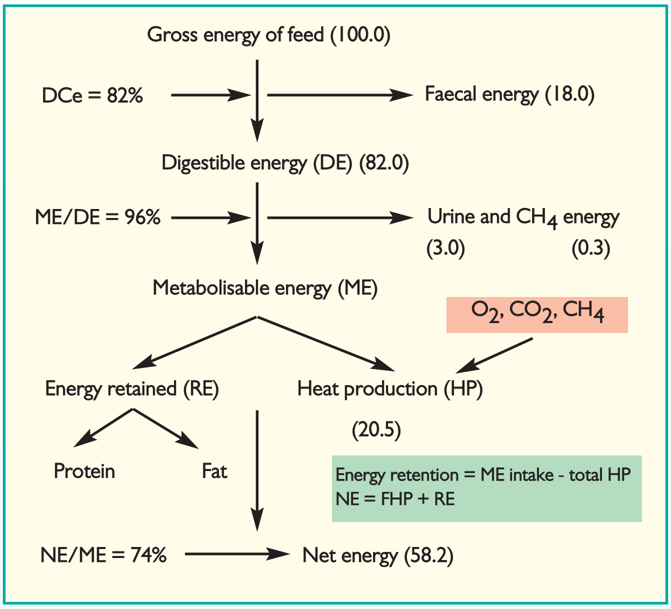

Fig. 1. Energy utilisation in pigs.

Optimal carcase quality

Several studies have shown that finishing pigs fed low-CP diets with crystalline amino acids added are fatter than pigs fed amino acids from intact protein sources.

Low CP diets reduce the deamination of excess amino acids, the consecutive synthesis and excretion of urea in urine, and lower body protein turnover and heat production in the animals. Thus, the use of low CP diets increases the quantity of energy that is available for tissue deposition and tends to produce fatter carcases due to excess in energy.

This provides commercial nutritionists with an excellent opportunity to reduce dietary ME parallel to the reduction in CP.

The commonly used energy evalu-

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Table 1. Nutrient recommendations for swine feeds in Indonesia, the Philippines and Thailand.

	Starter			Grower			Finisher		
	Indonesia	Thailand	Philippines	Indonesia	Thailand	Philippines	Indonesia	Thailand	Philippines
Moisture (maximum %)	14		13	14		13	14		13
Crude protein (minimum %)	17	18	18	15	16	16	13	14	14
Crude fat (minimum %)	7		6	7		4	7		3
Crude fibre (minimum %)			4			4			5
Crude ash (minimum %)	7		5	8		5.5	8		6
ME Kcal/kg (minimum)	2900	3250		2900	3150		2900	3150	
Phosphorus, avail. (minimum %)	0.40	0.32		0.32	0.50		0.23	0.50	
Calcium (minimum %)	0.9-1.2	0.70		0.9-1.2	0.60		0.9-1.2	0.60	
Lysine (minimum %)	1.05	0.95		0.90	0.75		0.70	0.60	
Methionine + cystine (minimum %)	0.35	0.48		0.30	0.41		0.30	0.34	

	DE	ME	NE	ME : DE	NE : ME
Alfalfa meal	1880	1705	540	0.91	0.32
Barley	3120	3040	1980	0.97	0.65
Corn	3490	3380	2270	0.97	0.67
Wheat	3360	3200	2215	0.95	0.69
Wheat shorts	3025	2835	1795	0.94	0.63
Soya bean meal (47%)	3680	3385	1760	0.92	0.52
Soya bean oil	7560	7280	5500	0.96	0.76

Table 2. Energy contents (kcal/kg) of selected feed ingredients in DE, ME and NE systems.

No.	Equation	R2
1	NE = 0.703 x DE + 1.58 x EE + 0.47 x ST – 0.97 x CP – 0.98 x CF	0.97
2	NE = 0.700 x DE + 1.61 x EE + 0.48 x ST – 0.91 x CP – 0.87 x ADF	0.97
3	NE = 0.730 x ME + 1.31 x EE + 0.37 x ST – 0.67 x CP – 0.97 x CF	0.97
4	NE = 0.726 x ME + 1.33 x EE + 0.39 x ST – 0.62 x CP – 0.83 x ADF	0.97
5	NE = 2875 + 4.38 x EE + 0.67 x ST – 5.50 x Ash – 2.01 x NDF – ADF) – 4.02 x ADF	0.93

CP; EE, ST, CF, ADF, NDF for crude protein, ether extract, starch, crude fibre, acid detergent fibre and neutral detergent fibre respectively.

Table 3. Regression equations for NE calculation (Noblet et.al, 1994).

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ation of feed ingredients is based on digestible energy (DE) or ME. NE is defined as ME minus heat increment associated with the utilisation of ME and the energy cost of ingestion and digestion of the feed. NE is the only system which takes this biggest single energy loss of about 20.5% of gross energy into account.

NE provides the closest estimate of the 'true' energy available for maintenance and production (Fig. 1) as compared to DE and ME.

The NE system is not only physiologically superior to DE or ME. It also entails a change in the relative monetary evaluation of protein rich versus starch rich ingredients in least cost formulation as concerns their cost per unit of energy. This can affect feed composition and potentially reduces feed cost per ton as energy is by far the most expensive nutrient.

Table 2 shows DE, ME and NE contents of different common feed ingredients.

The ME content for pigs of, for example, corn and soya bean meal, are approximately the same (3490 and 3680kcal/kg, respectively).

However, the NE content of soya bean meal is considerably lower than of corn due to SBM's high protein content and the associated high loss of energy via metabolic heat.

This means that the cost of soya bean meal per unit of NE is relatively high compared to starch rich ingredients. As a result, diets which are least cost optimised and based on NE usually contain less high protein ingredients like soya and more starch rich ingredients. Such diets are usually lower in protein content and cost per ton, provided minimum protein restrictions in least cost formulation are set low enough to allow for this to take effect.

The ME:DE and NE:ME ratios in Table 2 suggest that DE and ME systems in general, overestimate the energy value of high protein and high fibre feedstuffs, whereas, feed ingredients high in starch are underestimated in that respect. For individual feedstuffs, NE values are calculated from crude nutrients by regression equations, specifically developed for feed evaluation (Table 3).

The benefits derived from the use of low protein diets include:

- **Improved gut health.**

The pre-weaned pig is capable of having a growth rate of more than 300g per day, which often is not achieved due to post weaning diarrhoea. With the ban of prophylactic antibiotics in animal feeds, the use of low protein diets helps to reduce excess protein available for undesirable bacterial growth in the large intestines. Moreover, the excess protein in the gut remains unabsorbed at the terminal ileum, which becomes a substrate for growth and proliferation in the large intestines, a major cause for scouring.

- **Reduced nitrogen and ammonia excretion.**

The effect of feeding low dietary CP level on nitrogen excretion in piglet feeds is presented in Table 4. The diets were formulated to contain about 10.4 MJ NE/kg and 1.01g standard digestible lysine/MJ NE.

The ratios for digestible threonine, methionine + cystine, tryptophan, isoleucine and valine were at least 65, 60, 19, 60 and 70% of the digestible lysine supply, respectively.

The lowest feed intake was observed in the diet containing the highest CP level (Diet 1).

These results agree with those obtained by Hansen et al. (1993) and Jin et al. (1998), who observed that diets with amino acids coming only from protein bound amino acids result in excesses or imbalance that may be detrimental for feed intake in young pigs.

No significant differences were obtained in weight gain and feed efficiency across all diets. A marked reduction in nitrogen excretion was observed from diets 1-4.

These results clearly show that reducing CP level in the diet is an effective approach in reducing the amount of nitrogen excretion which translates to about 8% reduction for every point of CP reduction in the diet.

The results obtained however, were slightly lower than the 10% reduction in nitrogen excretion as earlier reported by Dourmad et al. (1993) and Le Bellego et al. (2001).

Another trial was conducted to determine the effect of three dietary levels of CP (16.5, 14.5 and 12.5%) on the nitrogen excretion and ammonia emission in growing finishing pigs.

Eighteen barrows, weighing 55kg, were housed in three different rooms and were fed three different diets. Ammonia emission was measured directly from the compartments. Results showed that the level of dietary CP did not influence feed intake, daily gain and feed conversion and carcase characteristics (Table 5). Nitrogen intake decreased when dietary CP level decreased.

This, in turn, reduced urinary nitrogen excretion volume and a significant reduction of ammonia emission in the slurry. Ammonia reduction was reduced by as much as 10-12.5% for each percentage

Table 4. Effect of dietary crude protein level on performance, nitrogen excretion, water intake, urine production and piglet faeces consistency.

Diet	1	2	3	4
Dietary CP (%)	22.4	20.4	18.4	16.9
Body weight (kg)				
Initial	11.7	12.0	11.8	12.0
Final	26.0	26.8	27.2	26.8
Feed intake (g/day)	959[a]	1039[b]	1061[b]	1048[b]
Weight gain (g/day)	642	661	690	663
Feed/gain	1.50	1.58	1.54	1.58
Total nitrogen excretion (g/day)	10.7[a]	9.4[a]	6.8[b]	5.1[c]
Nitrogen retention (g/day)	17.8	17.7	18.5	15.6
Water consumption (g/day)	1941	1887	1867	1645
Urine (g/day)	757	643	625	481
Faeces consistency (%)[1]				
Hard	81.9	82.0	95.4	89.0
Soft	14.7	14.5	4.1	9.0
Liquid	3.4	3.5	0.5	2.0

[1]Days with hard, soft or liquid faeces in percent of total number of days in the experiment.
[a,b,c] Different superscripts indicate significantly different means (p<0.05)

	High	Medium	Low	P
CP (%)	16.5	1.45	12.5	
NE, (MJ/kg)	9.38	9.38	9.38	
Ileal dig. lysine (%)	0.71	0.71	0.71	
Performance results				
Initial weight (kg)	54.8	54.9	54.8	NS*
Final weight (kg)	105.6	107.3	105.7	NS
Feed intake (kg/d)	2.361	2.341	2.334	NS
Weight gain (g/d)	793	819	795	NS
Feed conversion	2.98	2.86	2.94	NS
Ammonia emission of slurry (g/d/pig)	9.44	6.94	4.79	<0.001
Relative (%)	100	73	51	

**NS – not significant p >0.05*

Table 5. Effect of reducing dietary nitrogen on performance and ammonia emission of slurry.

Dietary crude protein (%)	18.5	12.9
Feed intake (g/d)	2290	2340
Weight gain (g/d)	781	754
Feed conversion	2.93	3.1
Water intake (g/day)	4270	3390
Relative	100	79
Total water excretion in urine and faeces (g/day)	3445	2266
Relative	100	66
Nitrogen intake (g/day)	67.8	48.3
Total nitrogen excretion (g/day)	41.8	25.5
Relative	100	61
Dry matter content of slurry (%)	11.7	17.1

Table 6. Water and nitrogen balance in growing pigs fed diets containing two protein levels.

	High	Medium	Low	Diet
Dietary CP (%)	16.5	14.5	12.5	effect
Weight gain (g/d)	805	805	797	NS
Feed intake (g/d)	2249	2245	2257	NS
Feed/gain ratio	2.75	2.75	2.79	NS
Backfat thickness (mm)	15.2	15.4	15.9	NS
Lean meat (%)	57.2	57.1	56.7	NS
Muscle thickness (mm)	56.9	56.5	57.0	NS

NS – not significant p >0.05

Table 7. Effect of reducing dietary CP on performance and carcase characteristics of 52-104kg BW pigs.

Dietary CP (%)	17.8	15.5	Diet effect
DE, (MJ/kg)	14.1	13.9	$p < 0.05$
NE, (MJ/kg)	10.2	10.2	-
Performance			
Feed intake (g/d)	2292	2319	NS
ADG (g/d)	846	867	NS
FCR (kg/kg)	2.71	2.68	NS
Carcase characteristics			
Dressing percentage	80.9	81.2	NS
Muscle content (%)	51.3	52.3	NS
Carcase fat content (%)	19.1	18.4	NS

NS – not significant p >0.05

Table 8. Effect of dietary crude protein level on performance of growing pigs (29-103kg).

point reduction in crude protein level.

● **Decreased slurry volume and the effect of water intake.**

Urine excretion is one way of expelling excess nitrogen in the pigs' body though urea formation. This process alters the water balance in pigs. Thus, reducing the dietary crude protein content reduces the pig's water intake. Fremaut and Schrijver (1991) fed growing finishing pigs diets with a high and a low CP level and closely monitored for water intake and urine excretion. Throughout the trial, water was available ad libitum. No significant differences were observed for feed intake for both protein levels.

Reducing the nitrogen intake of pigs from 67.8 vs. 48.3g/d was associated with a reduction in water intake by 21% as well as a reduction in water excretion and in nitrogen excretion of 34 and 39%, respectively (Table 6).

These results were in line with Le Bellego et al. (2002), who observed a 15% reduction in water consumption which in turn reduced urine volume by 35% with reducing CP levels from 22.4 to 16.9%.

Therefore, the reduction in slurry volume translates to less manure storage capacity needed, less transport, spreading and cleaning time aside from the benefits derived from reduced fixed and variable costs.

● **Comparable production performance and carcase qualities.**

Canh et al. (1998) conducted a trial to determine the effect of low CP levels in growing-finishing pig's production performance with a digestible lysine (g) to energy (MJ:NE) ratio of 0.76 for all treatments. Results showed no significant difference in terms of feed efficiency, backfat thickness, lean meat percentage and muscle thickness (Table 7). These results are in line with the findings of Le Bellego et al. (2000), who observed that neither feed conversion nor lean meat percentage was affected by the reduction in CP with 0.85 and 0.70g standardised ileal digestible lysine/MJ NE in the growing and finishing phase, respectively. These results clearly show that reducing the CP level in the diet for growing-finishing pigs has no detrimental effect on performance when sufficient amounts of amino acids are supplied in the diet.

In a trial conducted by Dourmad et al (1993), 40 pigs were individually housed and fed ad libitum with decreasing crude protein levels and having the same NE content (Table 8).

Ratios of M+C, threonine and tryptophan to lysine in the diet were of at least 60, 65 and 18 to 100%, respectively. Results showed that with at least 70% digestible lysine and controlled NE intakes, the level of dietary protein neither affected the growth of the animals nor the carcase fat content at slaughter.

Another study by Rademacher et al. (1999) showed that dietary CP can be reduced to 16% in the starter (27-50kg BW), 14.5% grower (15-80kg BW) and 13.5% finisher diets (80-110kg BW) without any reduction in growth rate, feed intake, feed efficiency and carcase quality, for as long as the diets are formulated based on standardised ileal digestible amino acids and the limiting amino acids are supplemented according to the ideal protein concept.

● **Reduction in total feed cost.**

Rademacher and Hagemann (2004), conducted a trial to determine the effect of energy systems and reducing dietary crude protein in growing-finishing pigs. The parameters noted were production performance, carcase characteristics and feed costs.

A total of 126 Pietrain hybrid pigs were fed a three phase feeding programme (Table 9) and within each growth phase, three diets (A, B and C) were formulated to provide similar digestible amino acid contents.

In each phase of growth, diet A was formulated on ME and standard dietary crude protein level, diet B was formulated on reduced CP levels and on ME basis, while diet C was formulated with the same CP content as diet B but taking into account the NE values in diets A and B.

Even though diets formulated based on NE concept (Group C) have a generally lower CP content and subsequently a higher supplementation of amino acids, these still proved to be more economical (Table 10).

A reduction on total feed cost of €0.63, carcase value was improved by €1.10. Profit (carcase value minus feed cost) was increased by €1.73 when comparing the overall costs of group A vs group C. In Europe, improvement in carcase quality is of high monetary value due to grading of meat according to its back fat thickness and loin eye area.

This, however, has yet to come to Asia to fully realise the economic benefits brought about by the improvements in carcase quality.

	Phase I			Phase II			Phase III		
Body weight range	30- 50kg			50-80kg			80-110kg		
Treatment	A_1	B_1	C_1	A_2	B_2	C_2	A_3	B_3	C_3
Dietary CP content (%)	19.0	16.9	16.9	18.0	16.0	16.0	17.0	15.0	15.0
ME (MJ/kg)	13.5	13.5	13.4	13.2	13.2	13.1	13.0	13.0	12.9
ME(Kcal/kg)	3227	3227	3203	3155	3155	3131	3107	3107	3083
NE (MJ/kg)	9.58	9.64	9.58	9.41	9.47	9.41	9.28	9.33	9.28
NE (Kcal/kg)	2290	2304	2290	2249	2263	2249	2218	2231	2218
Feed cost per 100kg (€)*	16.82	16.78	16.67	15.80	15.77	15.65	14.95	14.92	14.80

**Feed ingredient prices EU, Spring 2005*

Table 9. Effect of reduced dietary protein and energy system on growing-finishing performance.

Conclusion

The reduction in CP levels in swine feeds was proven to be effective when used with the NE concept and when optimal amino acid balance is maintained in the feed it allows production performance to maintain or even improve carcase quality.

For every percentage point reduction in CP levels in the feeds translates to a reduction of 10% reduction in nitrogen excretion, 3% in water consumption and 5% manure volume. For practical purposes, the dietary ME specification can be reduced by about 0.1 MJ ME/kg for each percent point reduction in dietary crude protein.

Some of the main swine producing countries in Europe have already successfully adopted this concept. It also has the potential to greatly improve swine feed and meat economics in Asia-Pacific. ■

Table 10. Effect of reduced dietary protein and energy system on growing-finishing pig performance, carcase quality and economics.

Group/treatment	A Stand. CP, ME	B Low CP, ME	C Low CP, NE
Pig performance (30-110kg)			
Daily gain (g)	854[ab]	836[b]	868[a]
Daily feed intake (kg)	2.1	2.07	2.1
Feed:gain (kg/kg)	2.47	2.48	2.42
Carcase characteristics			
Carcase weight (kg)	88.7	89	89.3
Lean meat (%)	57.8	57.6	58
Lean meat (g/d)	422	411	431
Loin eye area (cm²)	50.2	51.9	51.5
Feed costs/carcase value			
Feed cost per pig* (€)	30.62	30.91	29.99
Feed cost per kg weight gain (€)	0.38	0.39	0.35
Carcase value** (€)	109.63	109.65	110.73
Profit (carcase value-feed cost) (€)	79.01	78.74	80.74

**refer to Table 2 for feed cost. **Base price: €1.20/kg carcase weight at 56% lean meat. Adjustment: + €0.02/% point. increase in lean meat above 56%*
[abc] means within a row that are significantly different are denoted by different superscripts.