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N° 25

Low protein diets for piglets

The post-weaning phase is a critical period in pig growth. The transition from sow milk to solid plant feedstuffs together with the evolution of the physiology of the digestive tract can sometimes lead to digestive disorders depressing growth and damaging the health status of the herd. These problems are further enhanced when restricting the use of antimicrobial growth promoters. Lowering feed protein level appears as a practical nutritional solution to decrease the incidence and severity of digestive disorders leading to diarrhoea problems. However, reducing the crude protein level in the feed requires an adequate nutritional system in order to control essential amino acid supply.

Indeed lowering the protein should not be done at the expense of growth, since good performance in the piglet phase is shown to improve the overall growth of the pigs. Heavy piglets are more resistant to environmental changes, transition to other feed, and go on to perform better in the follow-on accommodation.

How to design high performing low protein piglet diets ?

The present bulletin studies the impact of feed protein level on piglet growth and reviews piglet response to the modification of amino acids levels.

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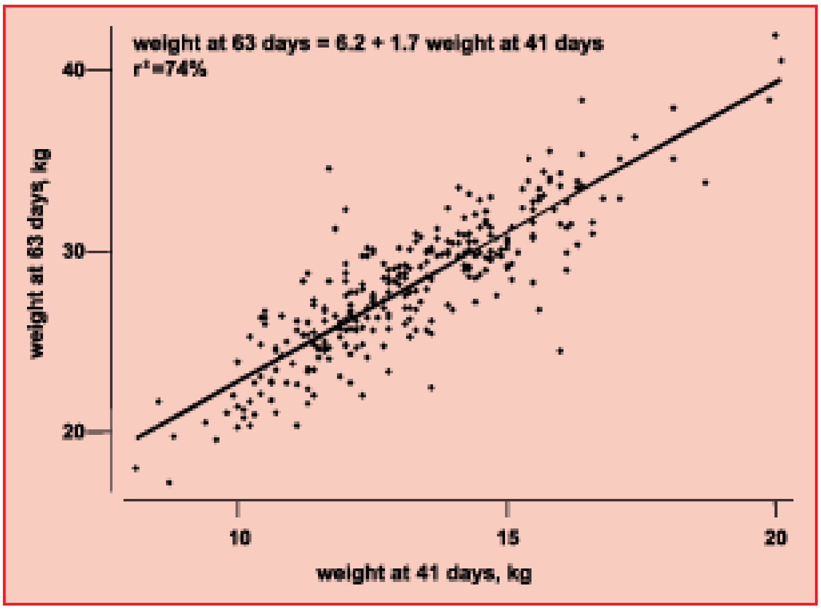
Info 1 Optimising performance in the piglet phase benefits the following stages

The aim of adequate piglet nutrition is not only to optimise growth during this critical phase but also to allow a higher performance level in the later stages of growth. The impact of piglet weight on subsequent growth stage is illustrated by the study from Brillouet (2002) where the pigs weight at day 63 (around 30 kg) is predicted by the piglets weight at day 41 (figure 1). According to this data set, one additional kilogram at day 41 corresponds to 1.7 additional kilogram at day 63. This confirms the impact of early growth on the subsequent stage.
In other words the heavier the piglet at day 41, the heavier the pig at day 63.

fig. 1 Relationship between body weight at 63 days and body weight at 41 days (Brillouet, 2002).



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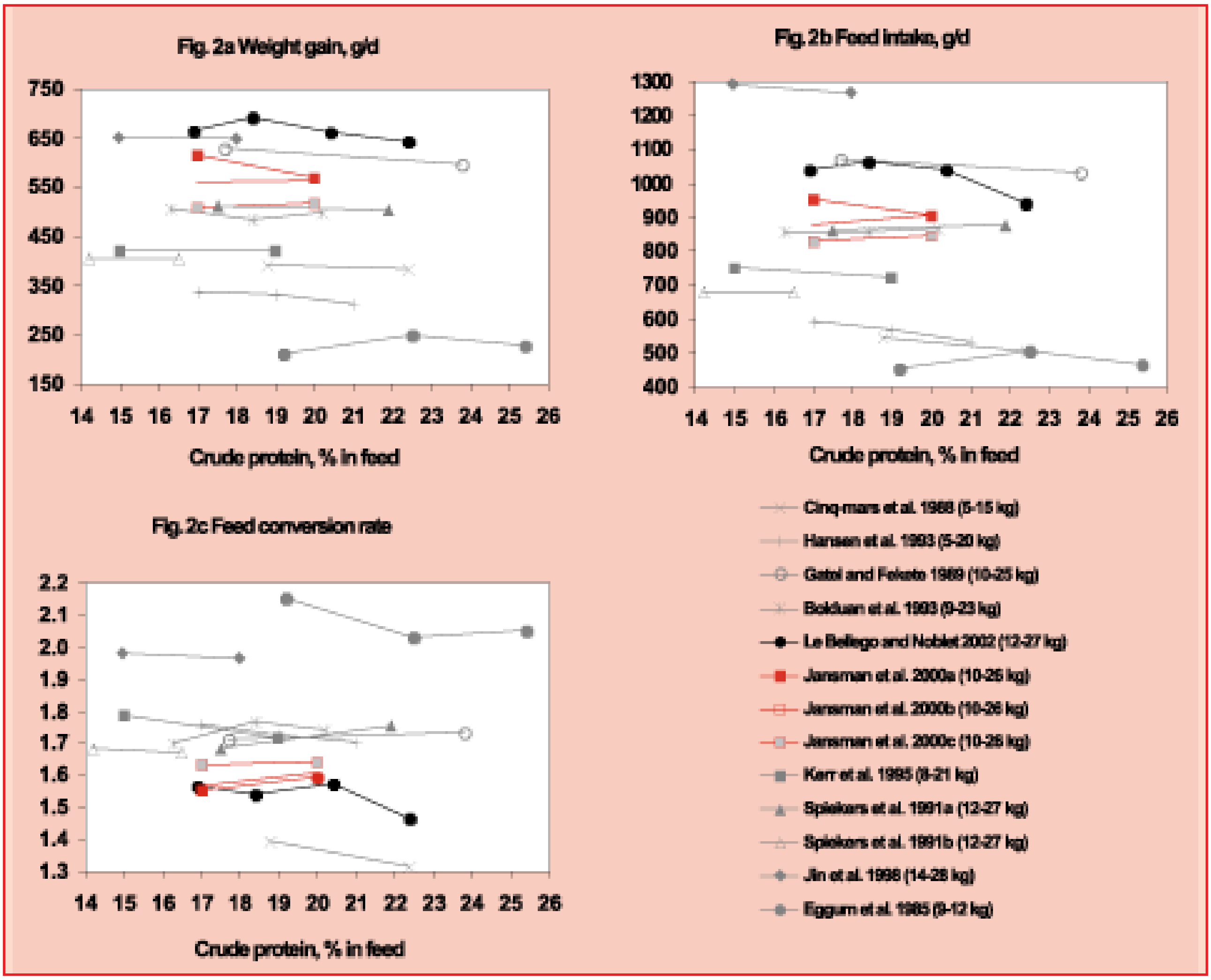
Porc Magazine

Piglets are not sensitive to the crude protein level in the feed

The effects of reducing the feed crude protein level was extensively investigated in growing finishing pigs (data reviewed in Ajinomoto Eurolysine bulletins 22 and 24), while only few experiments were published on piglets. A compilation of available data on piglets is presented in figure 2. These experiments confirm the possibility to reduce the crude protein level in the feed without affecting weight gain, feed intake and feed efficiency, provided that lysine level and essential amino acid profile are kept optimal.

fig. 2 Effect of the crude protein level in the feed on weight gain (a), feed intake (b) and feed conversion rate (c) in piglets.



Info 2 Why feed piglets diets with reduced protein content?

In young pigs, the occurrence and the severity of diarrhoea are more acute than at later stages. The main reasons are the transition from sow milk (liquid) to plant food (solid) and the limited acidification capacity of the immature digestive tracts of the piglet. The low acidification of the digestive bolus leads to a poorer digestion of the protein fraction and to a proliferation of pathogenic bacteria (as a result of both a higher pH and the extra nutrients made available for bacterial growth in the hind gut, figure 3).
Limiting feed protein level helps to decrease the amount of undigested protein reaching the lower part of the digestive tract and to some extent to lower the pH of the digestive bolus, low protein feedstuffs requiring less acid to optimise digestion (pH 4) (figure 4).

fig. 3 Role of acidification in the gut of the piglet

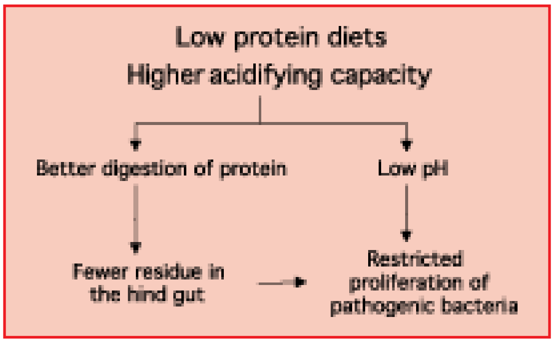
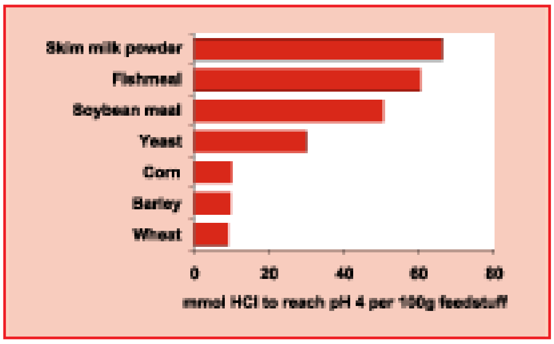


fig. 4 Buffering capacity of some feedstuffs according to Bolduan (1988)



Besides the theory, feeding low protein diets is acknowledged as one of the major nutritional solutions to decrease scouring problems on farm. Though difficult to reproduce in experimental facilities the impact of low protein diets on faeces consistency, as an indicator of digestive disorder, was documented in the trials presented here below (table 1)

tab.1 Effect of the crude protein level in the feed on diarrhoea in piglets

Eggum et al., 1985				
Crude protein, %	25.4	22.5	19.2	15.8
Diarrheoa cases, %[1]	17.0	16.0	11.0	7.0
Eggum et al., 1987				
Crude protein, %	26.6	23.1	19.5	
Diarrheoa cases, %[1]	14.0	3.0	4.0	
Bolduan et al., 1993				
Crude protein, %	20.2	18.4	16.3	
Diarrheoa cases, %[1]	3.2	2.4	0.8	
Le Bellego and Noblet, 2002				
Crude protein, %	22.4	20.4	18.4	16.9
Diarrheoa cases, %[1]	18.1	18.0	4.6	11.0

[1] *percentage of days with soft or liquid feces*

In the trial performed at INRA by Le Bellego and Noblet (2002), protein level was reduced from 22.5 down to 16.9 % (diets formulation based on digestible amino acids with the same amino acid profile) without detrimental impact on weight gain (table 2). Feed intake was even improved by decreasing feed protein level from 22.4 to 20.4%. Hansen et al. (1993) and Jin et al. (1998) previously reported such an impact, most likely due to the reduction of soybean meal inclusion. In the INRA trial, as well as in the Jansman et al. study, the control on piglet performance was allowed by an adequate amino acid supplementation (figure 5, table 2) which far from hindering protein utilisation helped to maintain a high performance level. While only lysine is reported in figure 5, it is however important to remember that the experimental diets were also balanced for threonine, methionine, tryptophan and, at the lowest levels of protein, a mix of valine and isoleucine. Besides the absence of sensitivity to protein level, these two studies also demonstrate that piglets are not sensitive to the amount of supplemental amino acids in the diet.

tab. 2 Effect of the crude protein level in the feed and free amino acid supplementation on performance of piglets from 12 to 27 kg body weight (Le Bellego and Noblet, 2002)

Crude protein, %	22.4	20.4	18.4	16.9
Ingredients, g/kg				
Wheat	203	220	240	266
Corn	193	218	235	238
Barley	203	220	240	266
Soybean meal	365	302	240	177
L-lysine HCl		2.0	4.0	6.0
DL-methionine	0.2	0.8	1.4	2
L-threonine		0.9	1.8	2.7
L-tryptophan			0.3	0.7
L-isoleucine			0.1	1.2
L-valine			0.9	1.9
Minerals and vitamins	36	36	36	39
Performance				
Feed intake, g/d	959^{a}	1039^{b}	1061^{b}	1048^{b}
Weight gain, g/d	642	661	690	663
Feed efficiency, kg/kg	1.50	1.58	1.54	1.58

a, b different superscripts indicates statistically different means ($P<0.05$)

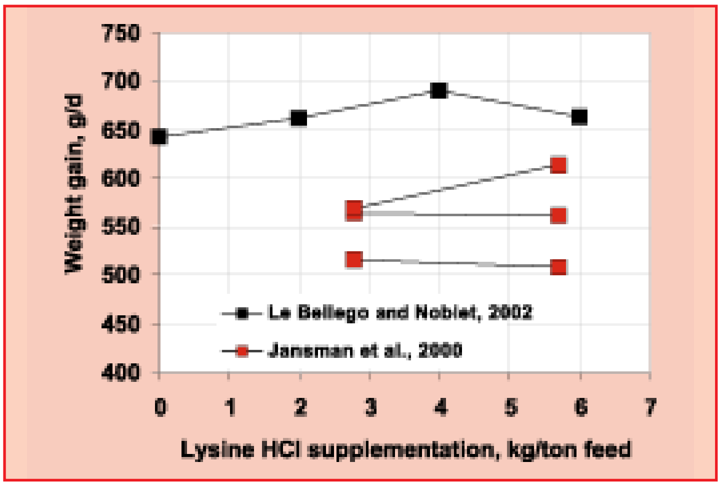
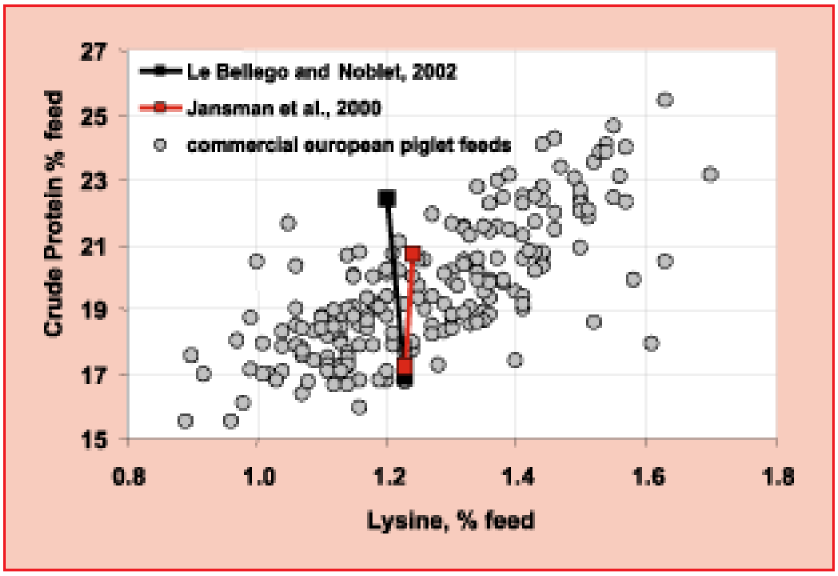


fig. 5 Weight gain plotted against L-lysine HCl inclusion rates in trials from Le Bellego and Noblet (2002) [12-27 kg] and Jansman et al. (2000) [10-26 kg].

The protein levels implemented by the two previous authors are compared in figure 6 with the protein levels measured in practice at the European level (200 commercial European piglet feeds, sampled in spring 2000, analysed in Ajinomoto Eurolysine laboratory). This graph gives an indication of how commercial feeds are positioned in terms of protein level, when compared with diets tested in experimental conditions.

fig. 6 Crude protein content according to lysine content in 200 commercial european piglet feeds and in trials from Le Bellego and Noblet (2002) and Jansman et al. (2000).



Optimal essential amino acid supply: the ideal protein

Piglets are not sensitive to feed protein level, nor to supplemental amino acids as long as they receive essential amino acids in appropriate quantities and proportion. Indeed should the threonine supply be too short, for example, when the lysine level is adequate, the animal would only value the lysine level made usable by the threonine level. In that example threonine is called limiting and extra lysine is then wasted. The best balance among essential amino acids is called the ideal protein. Most of the work done on the ideal amino acid profile focused on growing pigs, but a single reference study on piglets was done by Chung and Baker (1992, table 3). This amino acid profile can be considered as a starting point to further refinement.

tab. 3 The ideal amino acid profile in 10 to 20 kg piglets (Chung and Baker, 1992).

Lysine	100
Threonine	65
Methionine + cystine	60
Tryptophan	18
Isoleucine	60
Valine	68
Phenylalanine + tyrosine	95
Leucine	100
Arginine	42
Histidine	32

Which amino acid levels for high performing piglets ?

The following section of the document, starting from the Chung and Baker ideal protein profile, reviews the impact of amino acid enhancement with emphasis on lysine, threonine, methionine and cystine, and tryptophan because :

- these amino acids are limiting in pig and piglet feeding.
- their levels can be adjusted with industrial amino acids supplementation.

Essential amino acid requirement

1 - Lysine

As lysine is the first limiting amino acid in pig nutrition, its intake is one of the main factors determining piglet growth rate. Since feed intake is often limiting (figure 7) the only way to increase lysine intake is to raise the lysine concentration in the feed and to balance the feed to make sure that all the lysine provided can be valued for protein deposition (ideal protein concept).

fig. 7 Factors affecting lysine intake and weight gain in piglets

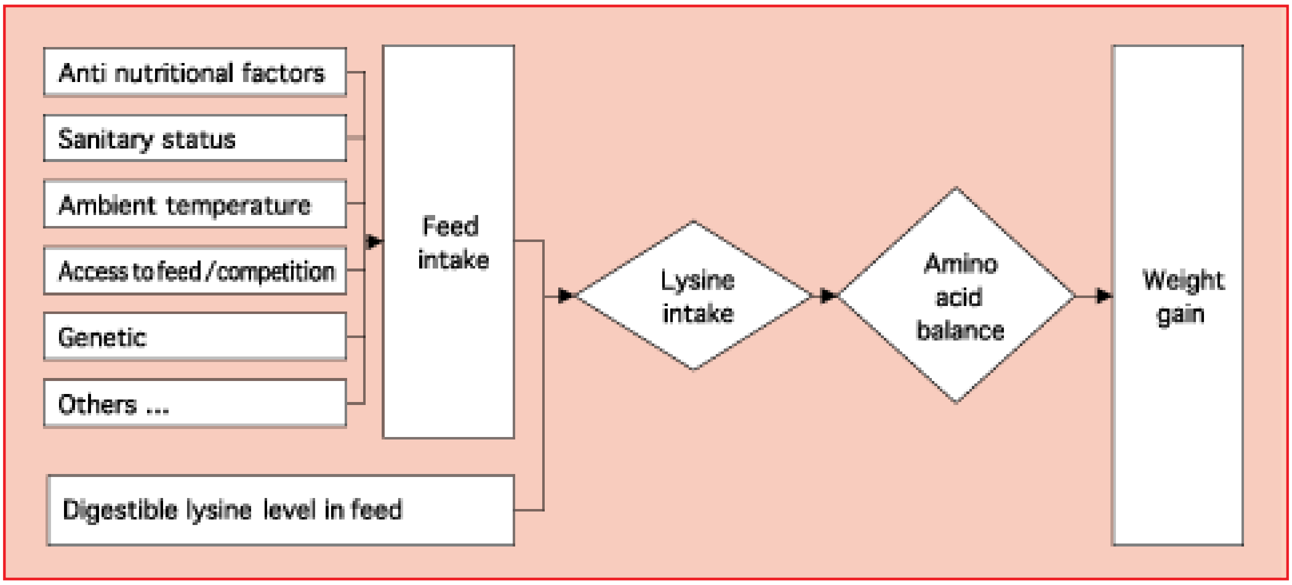


Figure 8 illustrates, using a compilation of trials (see table 10), the relationship between lysine intake and growth rate and feed conversion rate in piglets. Within each trial the improvement of lysine intake was achieved by an increase of lysine concentration in the feed through L-lysine addition. These relationships illustrate that the higher the growth potential, the higher the lysine requirement.

Info 3 Do low protein diets enhance fat deposition in piglets ?

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In piglets, the effect of dietary protein level on body composition from 12 to 27 kg body weight was reported by Le Bellego and Noblet (2002, comparative slaughter technique). Reducing the protein level in the feed with adequate amino acid supplementation does not impact upon the quantity and the amino acid profile of the deposited proteins. Likewise, lipid deposition rates were identical between treatments, which confirms that in piglets reducing dietary protein level in the feed has no effect on energy utilisation. These results mean that, at identical ME intake, reducing the protein level in piglet feeds will not lead to an increased energy and fat retention.

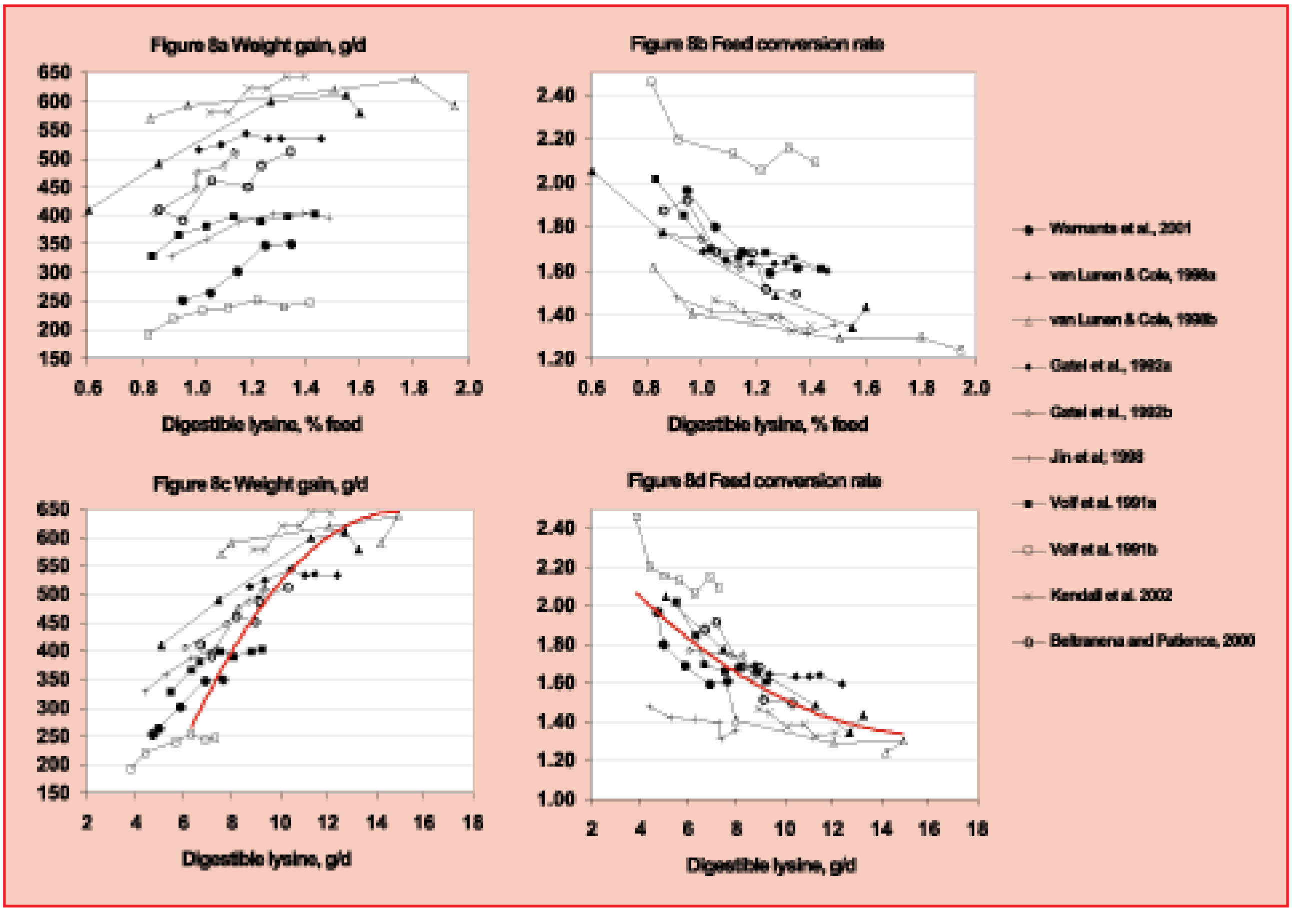
These results are opposite to those obtained in heavier animals by Noblet et al. (1994) and Le Bellego et al. (2001), respectively in 43 and 65 kg pigs. In these trials, reducing the protein level requires formulation on a NE basis in order to take into account the energy sparing effect of low protein diets and to control carcass fatness.

tab.4 Effect of the crude protein level in the feed on the composition of gain and energy utilisation in piglets fed ad libitum from 12 to 27 kg body weight (Le Bellego and Noblet, 2002)[1]

Crude protein, %	22.4	20.4	18.4	16.9	Effect
Gain, g/d/kg $BW^{0.60}$					
Empty body weight	113	109	111	109	*ns*
Proteins	19.2	18.9	19.2	18.4	*ns*
Lipids	12.4	13.2	13.1	13.3	*ns*
Energy balance, MJ/d/kg $BW^{0.60}$					
Heat production	1.6	1.58	1.58	1.57	*ns*
Energy retention	0.92	0.94	0.94	0.95	*ns*

[1] adjusted for a ME intake of 2.52 MJ/D/kg $BW^{0.60}$

fig. 8 Lysine impact on weight gain and feed conversion rate in piglets from 5 to 25 kg.



The average lysine requirement (% of feed) can be derived from the relationship between daily lysine intake and growth, and between growth and feed conversion rate observed in the present set of trials (table 5).

tab.5 Calculation of piglet lysine requirement (total and ileal standardised digestible basis) as assessed in the set of trials presented on figure 8.

Weight gain, g/d[1]	300	400	500	600
FCR[2]	1.9	1.7	1.6	1.4
Feed intake, g/d[3]	572	699	794	856
Digestible lysine intake, g/d	6.8	8.1	9.6	12.0
Digestible lysine, % feed[4]	**1.18**	**1.15**	**1.21**	**1.40**
Total lysine, % feed[5]	**1.31**	**1.28**	**1.35**	**1.55**

[1] *weight gain = -5.1416 x digestible lysine intake (g/d²)≤ +154 01 x digestible lysine intake (g/d) - 506 98 or digestible lysine intake (g/d) = - (-14.98 + square root (-0.194 x (weight gain (g/d) - 646.34)))*

[2] *calculated from the relationship between FCR and weight gain in the present trials: FCR = -0.0016 x weight gain (g/d) + 2.3873*

[3] *feed intake (g/d) = weight gain (g/d) x FCR*

[4] *ileal standardised digestible basis*

[5] *recalculated from [4] assuming a 90% digestibility coefficient for lysine*

2 - Threonine

Threonine is the second limiting amino acid in piglets feeds. Threonine intake should not only cover the requirement for protein deposition, but should also account for the threonine expense occurring in the digestive tracts through endogenous gut losses (brush border cell turnover and digestive secretions, Hess and Sève, 1999, Stein et al., 1999). Because of the involvement of threonine in gut function, threonine requirement is likely to vary according to the weight of the digestive tract, which is related to the weight of the animal.

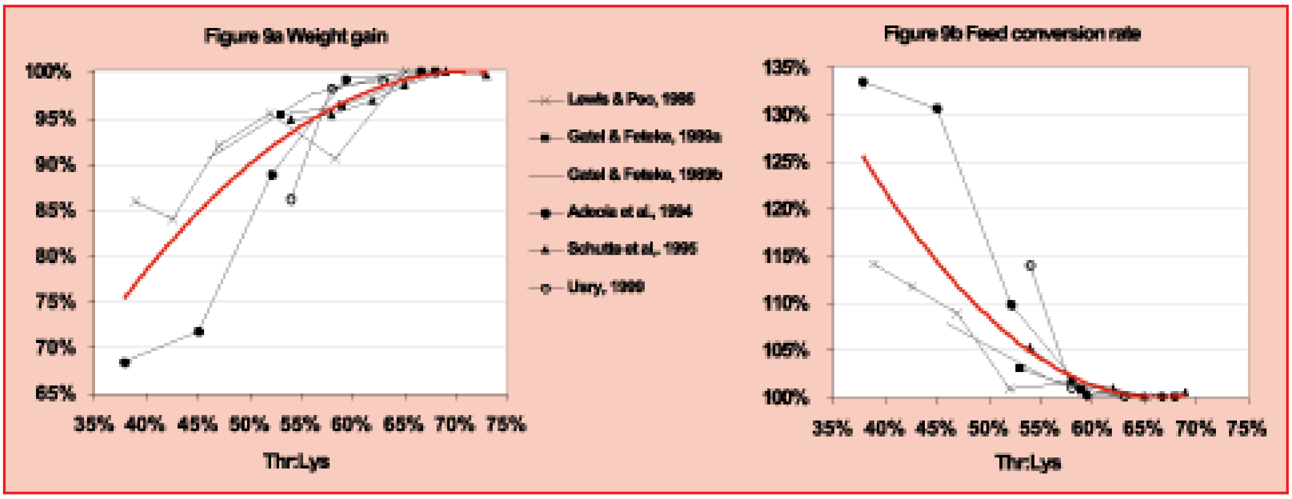
Trials presented in table 6 were performed on piglets from 4 to 25 kg (see also table 10). In order to compare the results, the lysine and threonine levels were recalculated from the feed composition using ileal standardised digestible coefficients (AmiPig, 2000, see Info 4). In each trial, the increase of Thr:Lys ratio is achieved through L-threonine addition in a common basal diet.

tab.6 Response of piglets to threonine balance expressed on an ileal standardised digestible basis.

Lewis & Peo, 1986	[4-14 kg]					
Thr:Lys	39	43	47	52	58	65
Feed intake, g/d	511	489	522	502	480	522
Weight gain, g/d	268	262	287	298	283	312
FCR, kg/kg	1.91	1.87	1.82	1.68	1.70	1.67
Gatel & Feteke, 1989a	[8-25 kg]					
Thr:Lys	53	59	68			
Feed intake, g/d	920	945	940			
Weight gain, g/d	526	532	552			
FCR, kg/kg	1.75	1.71	1.7			
Gatel & Feteke, 1989b	[8-25 kg]					
Thr:Lys	46	56	65	68		
Feed intake, g/d	1040	1070	1070	1030		
Weight gain, g/d	567	611	626	595		
FCR, kg/kg	1.84	1.74	1.71	1.74		
Adeola et al., 1994	[10-20 kg]					
Thr:Lys	38	45	52	59	67	
Feed intake, g/d	987	1011	1052	1072	1080	
Weight gain, g/d	337	353	437	488	492	
FCR, kg/kg	2.93	2.86	2.41	2.20	2.20	
Schutte et al., 1995	[10-20 kg]					
Thr:Lys	54	58	62	65	69	73
Feed intake, g/d	691	674	676	683	695	700
Weight gain, g/d	453	456	463	471	478	476
FCR, kg/kg	1.53	1.48	1.46	1.45	1.46	1.47
Usry, 1999	[11-23 kg]					
Thr:Lys	54	58	63	68		
Feed intake, g/d	735	741	741	757		
Weight gain, g/d	454	517	522	526		
FCR, kg/kg	1.62	1.43	1.42	1.44		

For consolidation purpose, since the trials were performed in different experimental conditions and on different genotypes, results are expressed as a percentage of the best response observed within each trial (figure 9).

fig. 9 Effect of the Thr:Lys ratio (ileal standardised digestible basis) on weight gain (a) and feed conversion rate (b) (relative to the best response within each trial) in piglets from 4 to 25 kg.



Piglet performance (weight gain and feed intake) are optimised when digestible threonine supply represents at least 65% of digestible lysine, corresponding on average to 67% total basis (see Info 4). From 60 to 67%, an improvement of 4% in weight gain and of 2% in feed conversion rate is obtained on average.

3 - Methionine and cystine

Methionine and cystine (M+C) are often limiting in piglet feeds, particularly when formulas include high levels of dairy products (see Info 6). The requirement for M+C is well established at around 60% of total lysine and is independent of the growth stage (Henry, 1993; NRC, 1998). An experiment conducted in a large commercial facility involving 1000 pigs from 11 to 27 kg, confirms an optimal M+C:Lys ratio at 58% (Usry, 2000; table 7).

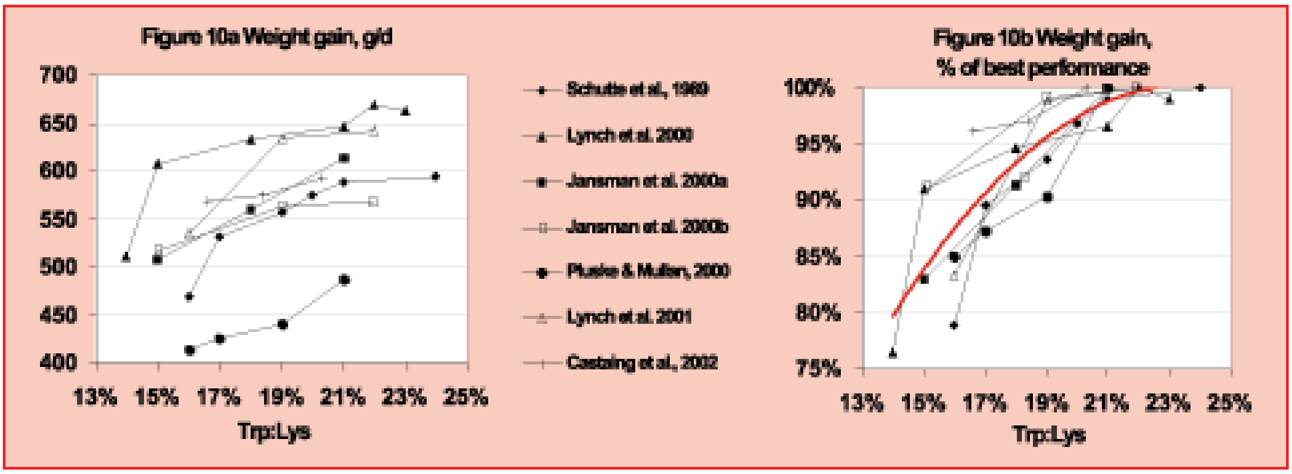
tab.7 Response of piglets to M+C:Lys ratio expressed on an ileal standardised digestible basis (Usry, 2000).

M+C:Lys, %	47	53	58	63	68
Weight gain, g/d	476	503	522	522	512
FCR, kg/kg	1.72	1.67	1.51	1.53	1.57

4 - Tryptophan

Tryptophan is involved in various metabolic pathways in addition to protein deposition. Part of the dietary tryptophan is metabolised in the brain into serotonine, a neurotransmitter involved in the regulation of feed intake (Henry et al, 1992). As a contributor to the regulation of feed intake, tryptophan is then key in piglet nutrition. A tryptophan to lysine ratio of 18% has long been recommended by many authors (Wang and Fuller, 1989; Chung and Baker, 1992 ; Henry, 1993; Baker, 2000). However, more recently, a series of trials quantified the gain resulting from Trp:Lys increase from 18% and up to 22% (Ajinomoto Eurolysine Information N°23). A summary of these studies is presented in figures 10 and includes additional results by Lynch et al. 2001 and Castaing et al. 2002 (see table 10). These results confirm that piglets weight gain is optimised when Trp:Lys reaches 22%.

fig. 10 Effect of Trp:Lys ratio (ileal standardised digestible basis) on weight gain in g/d (a) and in percent of the best performance within each trial (b) in piglets from 6 to 30 kg.



5 - Valine and Isoleucine

Though valine and isoleucine levels cannot be practically corrected through feed grade L-valine and L-isoleucine inclusion due to the absence of their commercial availability, these amino acids should also be monitored in current pig feed formulation. Rather little is known about the impact of a valine and/or an isoleucine deficiency, and Chung and Baker (1992) recommends ratios for Val:Lys and Ile:Lys of 68 and 60%, respectively (table 3).

Deficiencies in valine and isoleucine are likely to occur either:

- when the protein level is decreased beyond a certain level, or

- when the lysine level is raised beyond a certain level.

In practise, these critical levels occur in feeds where lysine represents more than 7% of the protein (Lys:CP > 7%). In such cases, Val:Lys and Ile:Lys ratios can drop to around 60% and 50% respectively.

However one should keep in mind that some authors managed, without controlling valine and isoleucine levels:

- either to maintain the same performance while decreasing dietary protein level (Jin et al., 1998),

- to increase significantly piglet performance when drastically increasing lysine, threonine, tryptophan and sulphur amino acids (Warnants et al., 2001).

The good level of performance obtained when these authors worked at valine and isoleucine levels below the recommended values of Chung and Baker suggest that the recommendations can be treated with some flexibility until further clear quantification of their impact is made available.

Conclusions

- Piglet feed protein level can be reduced without impacting performance, provided lysine and other essential amino acids are supplied at adequate levels.

- High levels of supplemental amino acids do not impair piglet performance, provided the feed remains balanced for the main essential amino acids.

- Lysine level set in the feed should account for both the potential growth rate of the piglets and their limited feed intake capacity.

- Growth and feed conversion rates are optimised when the feed is balanced for threonine with a threonine to lysine ratio at 65% (standardised digestible basis) and around 67% (total basis)

- Growth and feed intake are optimized when tryptophan to lysine ratio in the feed is raised above 18% up to 22%.

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Info 4 Amino acid levels expressed as, total, apparent ileal digestible or standardised ileal digestible amino acids

Why is the Thr:Lys ratio lower when expressed as ileal digestible amino acids than as total amino acids ?

In practical diets, lysine is generally more digestible than most of the other amino acids, as a result of a relatively high digestibility in protein rich feedstuffs combined with L-Lysine supplementation (100% digestible). Lysine being 3 to 6 % more digestible than threonine, for example, the ratio increases by 3 to 6 % when converting the ratio from digestible to total amino acids. The higher the contrast between lysine digestibility and other amino acids, the higher the shift in the ratio (table 8).

tab.8. Amino acid ratios in a piglet feed according to 2 different data sources for digestibility coefficients

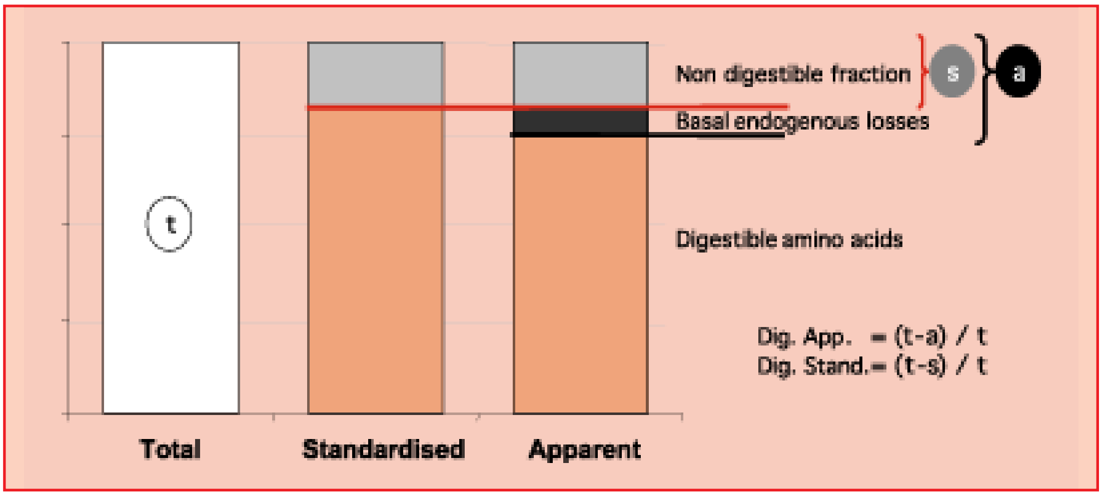
		Total	Stand. Dig.	App. Dig.
CP	AmiPig	18.2	15.8	15.1
	CVB	18.2	15.7	14.8
Lys	AmiPig	1.23	1.12	1.10
	CVB	1.23	1.12	1.09
Thr:Lys	AmiPig	67%	65%	64%
	CVB	67%	65%	63%
M+C:Lys	AmiPig	60%	60%	60%
	CVB	60%	59%	59%
Trp:Lys	AmiPig	20%	20%	20%
	CVB	20%	20%	19%
Val:Lys	AmiPig	67%	64%	63%
	CVB	67%	64%	62%
Ile:Lys	AmiPig	67%	64%	63%
	CVB	67%	64%	62%

Feed recipe in the example : 52% wheat, 10% barley, 10% corn, 17% soybean meal, 5 % full fat soybean, 0.05% L-Lys HCl, 0.02% L-Thr, 0.16% D-Met, 0.04% L-Trp and 5 % Vit-Min premix.

Why is there a difference between apparent and standardised digestible amino acids?

The difference between the two digestibility concepts lays in the consideration of the basal endogenous gut losses. These endogenous losses (made of gastric juices, brush border cells turnover and enzymes secretions) are taken into account in the calculation of standardised digestibility while they are not in the case of apparent digestibility (figure 11). As a result, digestible amino acids are lower when expressed as apparent rather than as standardised digestible amino acids.

fig. 11 Calculation of digestible amino acids according to apparent or standardised digestibility



Why a shift for Thr:Lys ratio when expressed as apparent or as standardised digestible amino acids ?

Endogenous losses have an amino acid profile that differs from body protein content. Endogenous losses are in general richer in threonine than in lysine (figure 12) and therefore threonine apparent digestibility is structurally lower than lysine apparent digestibility (from 2 to 5%). Hence the shift (from 2 to 5%) for the threonine to lysine ratio when expressed as standardised or as apparent digestible amino acids (figure 13).

Measurements of basal endogenous losses

Basal endogenous losses can be estimated through the collection of the protein flow reaching the end of the ileum of pigs consuming a protein free diet. This protein fraction, which is not from dietary origin, is considered as the basal endogenous losses. These losses occur in normal conditions whatever the feed ingested but depend on feed intake level.

fig. 12 Scope of variation of essential amino acid endogenous losses (Hess and Sève, 1999, 45 and 77 kg pigs fed 50, 70 or 90 g dry matter per kg$^{0.75}$)

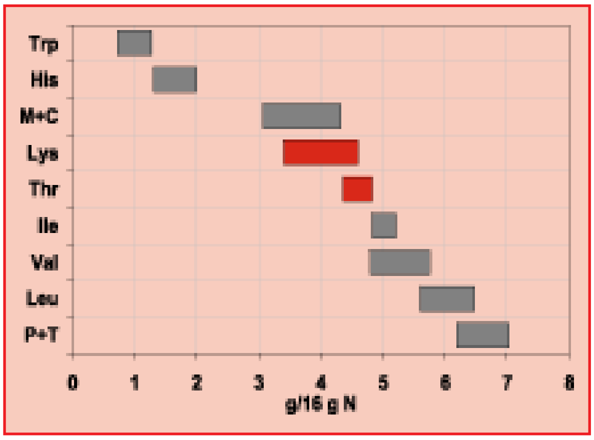
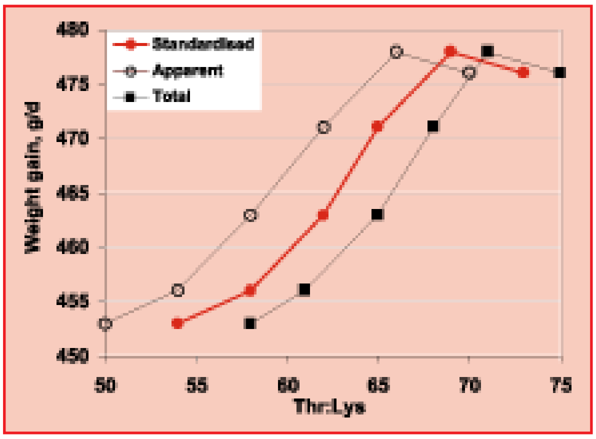


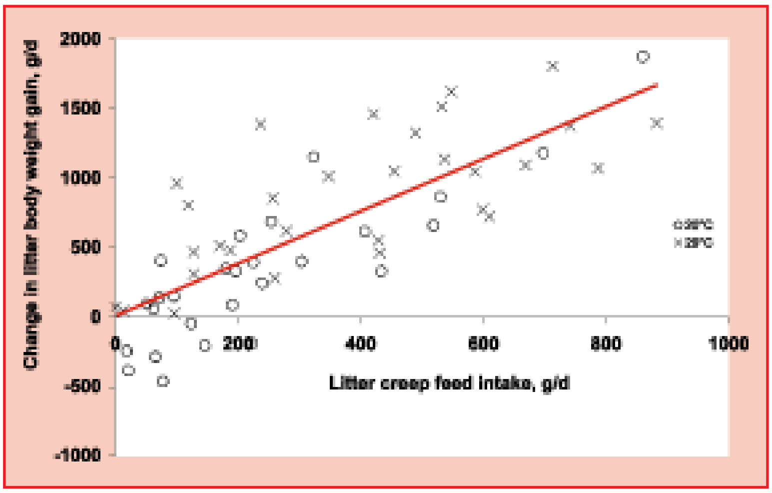
fig. 13 Interpretation of a trial result according to different amino acid evaluation systems (from Schutte et al., 1995)



Info 5 Early feed intake: piglet creep feed consumption

Creep feed intake in suckling piglets is generally low and variable: from 3 to 77 g/piglet/day (Pluske et al. 1995). In some cases where sow milk production is reduced, like in hot environmental conditions, creep feed consumption is enhanced. Both Quiniou et al. (2000) and Renaudeau and Noblet (2001) report the same increase in creep feed intake when raising ambient temperature, respectively, from 20 to 26°C : + 6 g/piglet/d and from 20 to 29°C : +15 g/piglet/d. The latter authors measure a higher litter weight gain resulting from a higher creep feed consumption (+ 2 g/g of creep feed intake, figure 14). The higher marginal efficiency of creep feed intake for body weight gain is explained by a higher protein:energy ratio in creep feed than in sow milk : 12.4 vs 10.8 g/MJ of gross energy, leading to higher protein deposition (at the expense of fat deposition). In addition to a better protein:energy profile, enhanced creep feed intake results in a better development of the digestive tract (also observed by De Passillé et al., 1989). These animals will then are able to better handle the dietary changes at weaning, and to put up with the weaning stress, which is favourable to higher feed intakes during the postweaning period and subsequent faster growth (Mahan and Lepine, 1991, Pluske and Williams, 1991).

fig. 14 Effect of creep feed intake (g/d) during the 4th week of lactation on the change of litter body weight gain (g/d) : y = 1.9 (±0.2) x ; (R^2 = 0.62; RSD = 361) (Renaudeau and Noblet, 2001).



Info 6 Amino acid profiles of feedstuffs specific of piglet nutrition

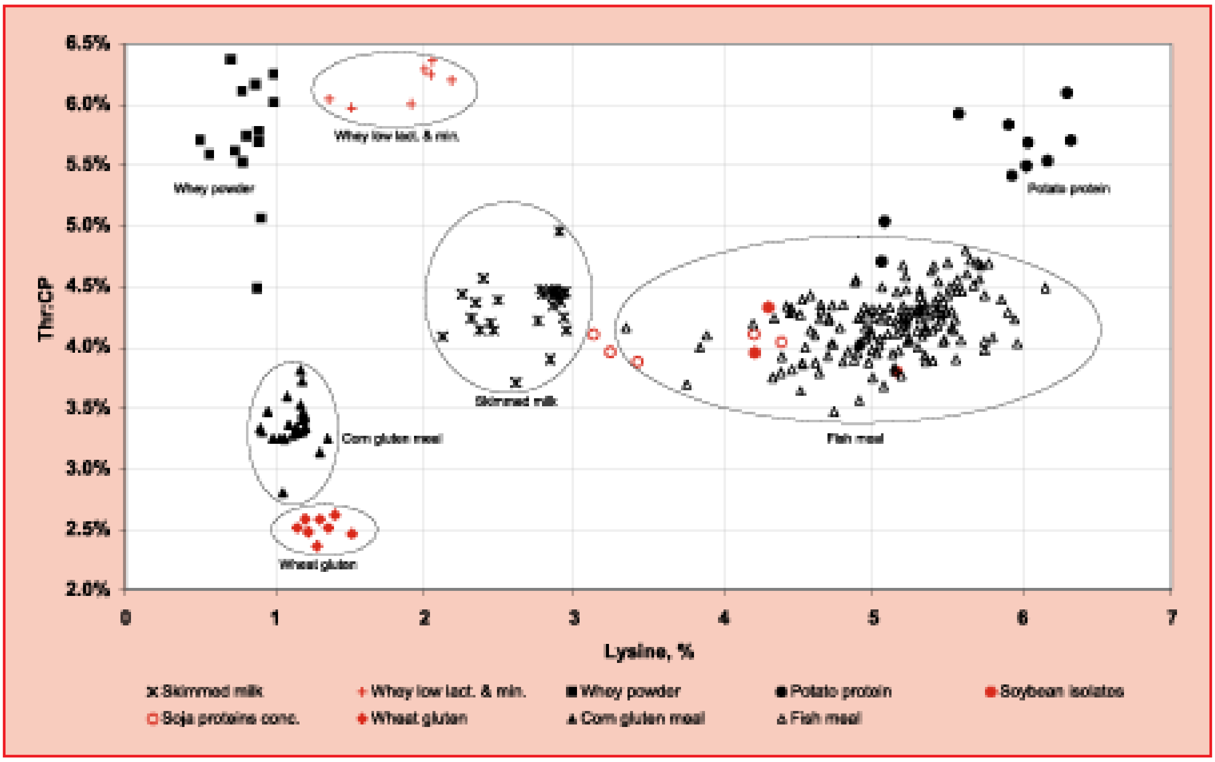
tab.9 Amino acid content in piglet feed specific ingredients (Association Française de Zootechnie[1] or Ajinomoto Eurolysine laboratory[2]).

	Skimmed milk	Whey low lact. & min.	Whey powder	Potato protein	Soybean isolates	Soja proteins conc.	Wheat gluten	Corn gluten meal	Fish meal	Fish meal
IO7 code	538	2136	AEL	1162	1346	AEL	1093	419	189	AEL
Mean										
DM, %	94.7	96.0	92.6	92.3	93.3	93.3	92.6	89.7	92.7	91.6
CP, %	34.0	25.4	10.4	77.4	68.4	60.8	80.5	60.3	65.0	67.4
Lys, %	2.68	1.86	0.77	5.43	4.31	3.68	1.31	1.03	5.02	5.21
Thr, %	1.48	1.56	0.59	4.01	2.78	2.45	2.01	2.11	2.77	2.86
M+C, %	1.22	0.86	0.31	2.74	2.01	1.76	3.21	2.62	2.36	2.47
Trp, %	0.44	0.36	0.13	0.99	0.86	0.79	0.71	0.31	0.54	0.76
Ile, %	1.84	1.45	0.53	4.40	3.56	2.79	3.00	2.57	2.85	2.90
Val, %	2.12	1.36	0.50	5.18	3.60	2.93	3.07	2.81	3.48	3.38
Standard deviation										
CP	2.2	2.9	1.8	2.7	7.6	5.7	2.3	2.6	3.4	3.4
Lys	0.25	0.31	0.14	1.43	0.32	0.58	0.12	0.13	0.60	0.35
Thr	0.14	0.20	0.08	1.04	0.26	0.26	0.11	0.20	0.28	0.16
M+C	0.14	0.09	0.08	0.22	0.06	0.15	0.55	0.37	0.38	0.18
Trp	0.03	0.04	0.04	0.06	0.07	0.08	0.03	0.01	0.07	0.06
Ile	0.18	0.20	0.08	0.39	0.54	0.27	0.33	0.15	0.36	0.18
Val	0.21	0.19	0.08	0.42	0.73	0.32	0.30	0.26	0.45	0.22
Observations (n)										
CP	47	7	15	89	20	5	9	474	834	68
Lys	29	7	15	13	9	5	9	23	100	68
Thr	29	7	15	10	5	5	8	15	96	68
M+C	28	7	15	9	5	5	8	19	41	68
Trp	21	6	14	4	4	5	3	5	5	48
Ile	29	7	15	8	3	5	8	15	97	68
Val	29	7	15	8	3	5	8	15	95	68

[1] from IO7 v.4.2 - (Association Française de Zootechnie © 2001, http://www.feedbase.com)

[2] AEL from Ajinomoto Eurolysine laboratory.

fig. 15 Focus on threonine profile in feedstuffs described in table 9



tab.10 Summary of protocols

	Reference[1]	Age at weaning, d	Weight range	Crude protein, %	Energy value MJ/kg	Animals per treatment	Housing
Lys	Wamants et al., 2001	28	8 to 25 kg	14.1 to 20.0	9.6 NE	66	groups of 6
	van Lunen and Cole, 1998a	-	9 to 25 kg	15.1 to 27.4	14.3 DE	7	individual
	van Lunen and Cole, 1998b	-	9 to 25 kg	16.0 to 30.2	16.4 DE	7	individual
	Gatel et al., 1992a	-	8 to 25 kg	20.0	13.9 DE	108	groups of 6 or 7
	Gatel et al., 1992b	-	8 to 25 kg	16.0 to 22.9	13.8 DE	136	groups of 6 or 7
	Jin et al; 1998	21	6 to 15 kg	18.33 to 21.83	3.4 ME	20	-
	Volf et al. 1991a	-	7 to 14 kg	19.1	-	14	groups of 14
	Volf et al. 1991b	-	7 to 14 kg	19.2	-	10	groups of 10
	Kendall et al. 2002	-	11 to 24 kg	21.5	13.6 ME modified	36	groups of 4
	Beltana & Patience, 2000	15	5 to 20 kg	22.4 to 26.8	14.6 DE	40	groups of 5
Thr	Lewis & Peo, 1986	21-28	4 to 14 kg	15.9	-	16	groups of 4
	Gatel & Fekete, 1989a	28	8 to 25 kg	20	13.5 DE	105	groups of 6 or 7
	Gatel & Fekete, 1989b	28	8 to 25 kg	17.7 to 23.8	13.5 DE	96	groups of 6 or 7
	Adeola et al., 1994	-	10 to 20 kg	18.1	-	6	individual
	Schutte et al., 1995	-	10 to 20 kg	18.5	9.7 NE	40	groups of 10
	Usry, 1999	-	11 to 23 kg	19.0	13.9 ME modified	220	groups of 22
Trp	Schutte et al., 1989	-	9 to 26 kg	18.1	9.8 NE	36	groups of 9
	Lynch et al. 2000	28	11 to 30 kg	18.2	14.7 DE	16	groups of 2
	Jansman et al. 2000a	35	9 to 26 kg	17.2	9.8 NE	48	groups of 8
	Jansman et al. 2000b	35	9 to 26 kg	20.7	9.8 NE	48	groups of 8
	Pluske & Mullan, 2000	21-26	7 to 16 kg	19.1	14.4 DE	12	groups of 2
	Lynch et al. 2001	28	11 to 21 kg	18.5	14.7 DE	64	groups of 2
	Castaing et al. 2002	21	11 to 18 kg	19.2	9.9 NE	144	groups of 6

[1] *ad libitum feeding*

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