More local feedstuffs and lower nitrogen emission in slaughter pig production by decreasing dietary crude protein and using compensatory growth

Introduction

From environmental and economical point of views, it is of vital interest to minimise the input of protein in animal feeds. For pigs, the protein value of each feedstuff is directly correlated to the content of essential amino acids (EAA) and their digestibility in the small intestine. The requirements of the first four limiting EAA - lysine, threonine, methionine and tryptophan - are fairly well investigated. However, for the other essential amino acids the requirements are less well documented due to lack of performance data. Requirements of EAA for pigs (NRC, 2012) are based on data from experiments performed under varying conditions (such as genetic lines, dietary raw materials, health status and managing practices). Therefore, the national nutrient recommendations may need to be adjusted to suit prevailing production conditions. Thus, results presented by Høøk Presto *et al.* (2007) indicated that the requirements of amino acids for Swedish modern genetic slaughter pigs might be lower than the standard recommendations.

Commercially, pure lysine, threonine, methionine and to some extent tryptophan are used in feed formulations. These are almost 100% digestible in the small intestine of pigs and provide an excellent possibility to balance the EAA profile of the feed and lower the inclusion of protein and thereby the amount of protein feedstuffs.

The requirement of energy increases and the potential for muscle growth decreases with increasing age of the pig. Thus, the EAA requirements are higher at an early than at a late stage of growth. In order to meet the needs for optimal growth the recommendation is to apply phase feeding. This implies two or three feeds with lower EAA contents with increasing age of the pigs. However, there is a big variation in live weight within a batch of slaughter pigs, meaning most of the pigs theoretically will be under- or oversupplied with EAA. To overcome this problem feeds in practice are supplied with higher contents of EAA and crude protein than is commonly recommended, which results in wastage of nutrients and unnecessary high nitrogen emission.

Research has demonstrated that limiting supply of EAA during the early growth may be fully compensated for by an increased protein retention (Martinez-Ramirez *et al*., 2008 and 2009) and faster growth during the later phase of the production (Fabian *et al*., 2002 and 2004; Reynolds and O'Doherty, 2006). In addition, pigs fed insufficient amounts of EAA in the early growth phase had improved feed conversion ratio during the entire raising period and less excretion of nitrogen than phase fed pigs (Fabian *et al*., 2002 and 2004; Reynolds and O'Doherty, 2006). There are also indications that meat content of the carcass is favored in pigs with compensatory growth (Reynolds and O'Doherty, 2006; Yang *et al*., 2008). Pigs expressing compensatory growth may have increased muscle protein turn-over compared to conventionally fed pigs (Kristensen *et al*., 2004; Therkildsen *et al*., 2004). According to Bee *et al.* (2007), compensatory growth has a positive effect on the tenderness of pig meat due to increased proteolytic activity at time for slaughter. However, Heyer and Lebret (2007) did not find any effect on meat sensory characteristics.

In pigs, respiratory diseases are still very frequent. Lantmännen (1990) and Holmgren *et al.* (2009) reported a correlation between high feed protein content and the occurrence of pleuritis. High feed protein content also increases the risk of diarrhea (Rist *et al*., 2013). Less protein in the diet will reduce the water intake and the urine production, thereby improving the hygienic condition in the stable and reducing the amount of slurry. According to Nielsen (1995), a reduction of the crude protein level of a common dry slaughter pig diet with 2 percentage units increase the dry matter content of slurry with 50%. A reduction of 1 percentage unit crude protein in a cereal based dry diet will reduce the nitrogen output from a slaughter pig with approximately 15% (calculated from Vils, 2007).

Traditionally, the main locally produced protein feedstuffs in Sweden are rapeseed meal, peas and faba beans. In recent years, new varieties of faba beans have increased the interest of cultivating this crop. Rapeseed meal and faba beans contain different kinds of anti-nutritional factors (ANF), which limit the amount that can be included in the diet. According to current Swedish recommendations, the inclusion levels should not exceed 10% of rapeseed meal and 20% of faba beans on energy basis (Göransson *et al*., 2012). Other possible locally produced protein sources are different cereal based by-products such as wheat middlings and distilleries grains. Production trials concerning utilisation of different domestic feedstuffs with genetically high performing pigs under optimal health and housing conditions are few. Accordingly, there is a need for extended knowledge.

The aim of the present study was to investigate the effect of reducing the dietary content of essential amino acids and protein on performance of single and phase fed growing-finishing pigs and to investigate the potential to utilise different domestic protein feedstuffs in their diets.

Material and methods

General

This study was performed at the Swedish Livestock Research Centre at Funbo-Lövsta, Uppsala, in accordance with Swedish regulations for holding pigs. The study was performed in two experiments (Exp 1 and Exp 2) with totally 1048 (690 in Exp 1 and 358 in Exp 2) cross-bred female and entire male pigs vaccinated against boar taint (Swedish Yorkshire dams x Hampshire sires). Entire male pigs were injected twice (8 and 4 weeks before slaughter) with Improvac®, containing a modified form of GnRH (Pfizer Ltd; 2 ml per injection). The sires were randomly selected from those available for artificial insemination. The pigs were raised in pens with 8-10 pigs in each.

Each growing-finishing unit had 12 pens with 3.60 m long feeding through, 2 water nipples, 6.48 m^2 solid floor and a dunging area of 3.96 m^2. The pigs were provided straw every day (approx. 1 kg per pen and day). All pigs were restrictedly fed three times daily according to a standard feeding regimen for growing-finishing pigs (Andersson *et al*., 1997). Dry feed was mixed and distributed by an automatic device and the portioning accuracy of the feeding equipment was tested before each batch of pigs entered the experiment. At feed calculation, the net energy values and digestibility coefficients for amino acids were collected from Sauvant *et al.* (2004).

At weaning, piglets were randomly allocated to treatments with respect to gender, litter and live weight. The piglets stayed in the farrowing unit until the start of the experiment and were all fed the same piglet diet *ad libitum*. The weights of the pigs were individually recorded at start of the experiments and then fortnightly until their final weighing one day prior to slaughter. Feed consumption was recorded at each feeding occasion and feed conversion ratio was calculated pen-wise.

At slaughter, the carcass weight was recorded before cooling and lean meat content was determined with the Hennessy Grading Probe (Hennessy Grading Systems, Auckland, New Zealand; Sather *et al*., 1991). After slaughter, signs of tail-biting were recorded by an experienced technician using a 2-point scale (0: no visible tail damage; 1: tail damage).

Daily lean meat growth from start of the experiment to slaughter was calculated using the formula: % lean × (carcass weight - initial weight × 0.72)/days in experiment, with the value 0.72 representing a hypothetical dressing percentage at start (Andersson *et al*., 2012). The income per carcass was calculated based on carcass weight and lean meat content, according to prices from the co-operative slaughterhouse, contract note July 2015 in Exp 1 and July 2016 in Exp 2. Prices were converted from SEK into EUR (1 SEK = 0.11 EUR).

The study was approved by the local Ethics Committee on Animal Research, Uppsala, Sweden, and ensuring compliance with EC Directive 86/609/EEC for animal experiments.

Experimental design

Experiment 1

Four feeds, low lysine-low protein, low lysine-high protein, high lysine-low protein and high lysine-high protein, were manufactured at three occasions in a commercial feed plant (Lantmännen Västerås). At each manufacturing occasion, two samples of each feed were collected for analysis. Based on analysed data the four feeds were mixed by the automatic feeding machine in order to produce feeds for the 12 treatments according to Table 1. The analysed chemical composition is presented in Table 2. Within low and high lysine level, the total amount of digestible lysine from start to slaughter was calculated to be equal for single and phase fed pigs.

Table 1. Experimental design and calculated lysine and crude protein level in the experimental diets

Treatment	Feeding plan	Lysine level[1]		Crude protein level[2]
1	Singel	0.76		13.5
2	Singel	0.76		14.5
3	Singel	0.76		15.5
4	Singel	0.85		13.5
5	Singel	0.85		14.5
6	Singel	0.85		15.5
7	Phase	0.89	0.71	13.5
8	Phase	0.89	0.71	14.5
9	Phase	0.89	0.71	15.5
10	Phase	0.98	0.79	13.5
11	Phase	0.98	0.79	14.5
12	Phase	0.98	0.79	15.5

[1]Standardised ileal digestible (SID), g/MJ NE. [2]SID/SID lysine, g/g.

At start of the experiment the pigs were moved to the growing-finishing unit at an average age of 10 weeks (70.3 ± 3.1 days; mean ± s.d.) in batches 1 and 2; 9 weeks (63.1± 4.4 days) in batches 3 and 4, and 8.5 weeks (59.9 ± 5.9 days) in batches 5 and 6. The corresponding values for average initial live weight (LW) were 36.8 kg (s.d. 5.2 kg), 31.6 kg (s.d. 6.1 kg) and 28.3 kg (s.d. 6.6 kg). Pigs were slaughtered by split marketing based on individual weight at an average age of 148.6 days (s.d. 9.2 days) and an average LW of 117.3 kg (s.d. 6.2 kg).

Table 2. Analysed chemical composition of the experimental diets

Treatment	Phase	SID[1] lysine, g/MJ NE	g SID[1]/g SID[1] lysine					
			Crude protein	Threonine	Methionine +Cysteine	Tryptophan	Valine	Isoleucine
1	1 & 2	0.77	15.5	0.61	0.61	0.21	0.68	0.46
2	1 & 2	0.77	14.5	0.64	0.60	0.20	0.64	0.46
3	1 & 2	0.76	13.8	0.66	0.58	0.20	0.61	0.45
4	1 & 2	0.86	15.5	0.61	0.59	0.21	0.69	0.49
5	1 & 2	0.86	14.5	0.63	0.59	0.20	0.64	0.48
6	1 & 2	0.85	13.8	0.65	0.59	0.20	0.61	0.48
7	1	0.89	15.5	0.62	0.59	0.21	0.69	0.50
7	2	0.75	15.5	0.61	0.61	0.21	0.68	0.45
8	1	0.90	14.4	0.63	0.59	0.20	0.64	0.48
8	2	0.74	14.5	0.65	0.60	0.25	0.64	0.45
9	1	0.89	13.7	0.64	0.59	0.20	0.60	0.49
9	2	0.72	13.8	0.67	0.58	0.20	0.61	0.44
10	1	0.98	15.4	0.62	0.58	0.21	0.69	0.51
10	2	0.80	15.5	0.61	0.60	0.21	0.69	0.47
11	1	0.99	14.5	0.63	0.59	0.20	0.64	0.50
11	2	0.80	14.4	0.64	0.59	0.20	0.64	0.47
12	1	0.99	13.8	0.63	0.59	0.20	0.61	0.51
12	2	0.79	13.8	0.66	0.59	0.20	0.61	0.46

[1]Standardised ileal digestible.

Experiment 2

Exp 2 consisted of two trials, Trial 1 and Trial 2. The initial average age was 61.0 days (s.d. 5.0 days) in Trial 1 and 59.5 days (s.d. 4.9 days) in Trial 2. The corresponding values for LW at the start of the trials were 27.1 kg (s.d. 4.5 kg) and 26.4 kg (s.d. 4.1 kg). Trial 1 was divided into three consecutive batches with totally 6 pens per treatment, whereas Trial 2 consisted of two consecutive batches with a total of 5 pens per treatment.

Diet formulations and calculated chemical compositions are given in Table 3. In both trials, the reference diet was formulated as a commercial diet for growing-finishing pigs with soya bean meal (SBM) as the only protein feedstuff. In Trial 1, the protein feedstuffs in the test diets consisted of cereal by-products (CBP), rapeseed meal (RSM) and, 50% cereal by-products and 50% rapeseed meal (CBP+RSM). In Trial 2, the test diets included colour-flowered faba beans (FB) and, 50% colour-flowered faba beans and 50% rapeseed meal (FB+RSM). The diets CBP+RSM and FB+RSM were mixed by the feeding device on the research facility. Two feed samples were collected from each diet for chemical analysis and one sample of field beans was collected for analysis of ANF.

Slaughter was performed at an average age of 153.1 days (s.d. 11.4 days) and an average LW of 116.6 kg (s.d. 7.1 kg) in Trial 1. Corresponding values for Trial 2 were 151.3 days (s.d. 8.0 days) and 116.2 kg (s.d. 6.2 kg). Pigs were slaughtered by split marketing based on individual weight with a maximum of three occasions per batch.

Table 3. Feed ingredients and calculated chemical composition

	Trial 1			Trial 2		
	SBM	CBP	RSM	SBM	RSM	FB
Ingredients, %						
Wheat	41.30	13.90	40.70	35.10	40.90	30.90
Barley	41.30	47.90	40.70	35.10	40.90	30.90
Oats	0	0	0	13.4	0	8.80
Wheat brain	5.00	10.00	0	5.00	0	5.00
Wheat middlings	0	20.00	0	0	0	0
Dry distillers grain with solubles	0	4.00	0	0	0	0
Soya bean meal	8.00	0	0	7.20	0	0
Rapeseed meal	0	0	14.60	0	14.30	0
Faba beans	0	0	0	0	0	20,0
L-Lysine sulphate	0.62	0.74	0.63	0.56	0.61	0.51
L-Threonine	0.14	0.14	0.10	0.13	0.11	0.13
Dl-Methionine	0.08	0.05	0.03	0.06	0.03	0.12
L-Tryptophan	0.01	0	0.02	0.01	0.02	0.03
Calcium carbonate	1.26	1.22	1.09	1.23	1.08	1.20
Monocalcium phosphate	0.46	0.19	0.32	0.40	0.31	0.43
Vegetable fat	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin-mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Phytase	0.30	0.30	0.30	0.30	0.30	0.30
Calculated chemical composition						
MJ NE/kg	9.9	9.1	9.7	9.5	9.6	9.6
Crude protein, g/kg	130	127	133	127	132	131
SID[1] lysine, g/MJ NE	0.78	0.78	0.78	0.78	0.78	0.78
Threonine, g/kg	5.5	5.3	5.6	5.4	5.7	5.5
Methionine+cysteine, g/kg	5.3	5.1	5.7	5.1	5.6	5.2
Tryptophan, g/kg	1.69	1.54	1.73	1.64	1.73	1.69
Calcium, g/kg	6.7	6.1	6.6	6.5	6.5	6.5
Phosphorus, g/kg	4.70	5.20	4.80	4.54	4.78	4.64

[1]Standardised ileal digestible.

Statistical analyses

Data were analysed with the Statistical Analysis System, version 9.4 (SAS Institute, Cary, NC, USA). The effect of treatment on performance and carcass quality was evaluated with Proc Mixed. In Exp 1, the model included the fixed factors of feeding plan (single or phase), lysine level (low or high), crude protein level (low, medium or high) and gender (female or vaccinated entire male pigs). In Exp 2, the model included protein feedstuff (SBM, CBP, RSM and CBP+RSM in Trial 1 and SBM, FB and FB+RSM in Trial 2) and gender (female or vaccinated entire male pigs). The random factors were batch, litter within batch and pen within batch. Two-way interactions were tested and included in the model if found to be significant ($P \leq 0.05$). Pig was the experimental unit for carcass and all performance parameters, except for feed conversion ratio, where pen was regarded as experimental unit. Initial weight was included in the model as a covariate for the analysis of daily weight gain and carcass weight for lean meat content.

The prevalence of tail-biting was recorded at slaughter and tested as a logistic regression using a binomial distribution with a logit link function. This analysis was done with Proc Genmod and the model included the effect of feeding plan, lysine level, crude protein level and gender in Exp 1 and protein feedstuff and gender in Exp 2.

Results

Experiment 1

Six pigs died or were euthanised due to illness unrelated to the study. The average daily weight gain was high (1022 g/day) with a very low variation between the batches. The analysed feed compositions diverged somewhat from those that were calculated (Tables 1 and 2). Thus, the low lysine treatments in phase 2 got somewhat more lysine than planned and the treatments with the lowest level of protein were supplied with some more protein than intended. In terms of total supply of standardised ileal digestible lysine (SID; g/pig), the phase fed pigs got 1649 (low) and 1782 (high). Corresponding figures for single fed pigs were 1622 and 1797, respectively.

In the weight interval from start to 60 kg, phase fed pigs had, independent of dietary lysine and crude protein levels, significantly improved growth and feed conversion compared to the single fed pigs (Table 4). In the following period, single fed pigs totally compensated and daily weight gain and feed conversion for the entire raising period did not differ between single and phase fed pigs (1024 vs. 1019 g and 24.5 vs. 24.5 MJ NE/kg). Feeding plan had no significant effect on carcass traits. Consequently, no difference in income per carcass was observed between single and phase fed pigs.

Table 4. Effects of feeding plan and lysine level on performance in experiment 1

	Feeding plan			Lysine level		
	Single	Phase	P-value	Low	High	P-value
No. of pigs	340	344		341	343	
Initial weight, kg	32.0	32.2	0.420	32.2	32.0	0.640
Final weight, kg	117.3	117.4	0.821	117.0	117.7	0.103
Daily weight gain, g						
to 60 kg – phase 1	963	1007	<0.001	966	1004	0.001
after 60 kg – phase 2	1061	1031	0.007	1045	1047	0.807
start to slaughter	1024	1019	0.534	1015	1028	0.104
Feed conversion, MJ NE/kg weight gain						
to 60 kg – phase 1	21.7	20.5	<0.001	21.5	20.7	0.004
after 60 kg – phase 2	26.0	26.5	0.097	26.4	26.1	0.373
start to slaughter	24.5	24.5	0.935	24.8	24.3	0.035
Days in experiment	84.4	84.1	0.533	84.5	84.1	0.600
Carcass weight, kg	88.5	88.5	0.985	88.3	88.7	0.221
Lean meat content, %	59.1	59.3	0.362	59.1	59.3	0.237
Dressing percentage	75.5	75.4	0.385	75.5	75.4	0.380
Daily lean meat growth, g	463	463	0.917	460	466	0.083
Carcass value, €	145.2	145.4	0.735	144.8	145.8	0.094

Data are presented as least square means. Means with different superscripts within the row and feeding plan or lysine level differ at $P \leq 0.05$.

For both single and phase fed pigs, high dietary lysine level improved daily weight gain and feed conversion in phase 1 compared with the low level, whereas no difference was observed in phase 2. Overall, lysine level did not significantly affect daily weight gain, however, feed efficiency was significantly better for pigs fed the high lysine level (Table 4). Carcass traits were unaffected by lysine level. There was a tendency that lysine level improved daily lean meat growth, 466 g/day for pigs with high lysine level compared to 460 g/day for pigs with the low one (P=0.083). The income per carcass tended to be higher for pigs fed high lysine level compared to those given the low lysine level (145.8 vs. 144.8 EUR).

Vaccinated male pigs had on average a higher daily weight gain than female pigs, 1065 and 978 g, respectively. For vaccinated entire male pigs, dietary crude protein level had no effect on growth rate (Table 5). Female pigs grew faster during both phases with increased protein level and consequently during the entire raising period ($P<0.050$). The opposite effect was observed for lean meat content. Protein level did not affect lean meat content of females, whereas high level increased the proportion of lean meat in carcass of vaccinated pigs. Both females and vaccinated pigs fed the high protein level had significantly better feed efficiency than those pigs with low and medium levels.

Table 5. Performance of vaccinated male and female pigs raised mixed and fed different levels of crude protein

	Vaccinated male pigs			Female pigs			
	13.5[1]	14.5[1]	15.5[1]	13.5[1]	14.5[1]	15.5[1]	P-value
No. of pigs	115	116	116	112	112	112	
Initial weight, kg	31.9	32.5	32.3	32.0	32.0	31.9	0.663
Final weight, kg	118.7	118.5	118.9	115.0	115.9	117.0	0.212
Daily weight gain, g							
start to 61 kg - phase1	1002[a]	993[a]	980[a]	962[a]	979[ab]	994[b]	0.002
61 kg to slaughter - phase 2	1137[a]	1125[a]	1144[a]	923[a]	956[a]	991[b]	0.011
start to slaughter	1071[a]	1055[a]	1069[a]	949[a]	976[b]	1009[c]	0.001
Feed conversion, MJ NE/kg weight gain							
start to 61 kg - phase1	21.2	21.4	20.7	21.2	21.4	20.7	0.180
61 kg to slaughter - phase 2	26.7[a]	26.5[a]	25.7[b]	26.7[a]	26.5[a]	25.7[b]	0.018
start to slaughter	24.8[a]	24.7[a]	24.0[b]	24.8[a]	24.7[a]	24.0[b]	0.006
Days in experiment	80.8[a]	81.0[a]	80.8[a]	89.0[a]	87.5[ab]	86.2[b]	0.042
Carcass weight, kg	88.6	88.2	88.8	87.4	88.4	89.5	0.069
Lean meat content, %	58.1[a]	58.2[a]	58.8[b]	60.1[a]	60.1[a]	59.9[a]	0.029
Dressing percentage	74.7	74.4	74.7	76.3	76.2	76.4	0.789
Daily lean meat growth, g	475	472	483	438	451	461	0.083
Carcass value, €	144.0	143.8	145.4	144.7	146.2	147.8	0.416

Data are presented as least square means. Means with different superscripts within gender and rows differ at $P\leq 0.05$.
[1]g SID crude protein/g SID lysine.

There were no significant interactions between treatment (feeding plan, crude protein level and lysine level) and the initial weight of the pigs. The occurrence of tail biting recorded at slaughter was on average 3.7% (25 out of 668 pigs) and did not differ between feeding plan (P=0.518), lysine level (P=0.262), crude protein level (P=0.302) or gender (P=0.174).

Experiment 2

In Trial 1, the analysed contents of crude protein somewhat exceeded calculated values for the SBM and RSM diets (Table 6). Lysine content in the CBP diet was also somewhat higher than the calculated values. In Trial 2, the analysed contents of crude protein and lysine were well in line with calculated figures, except for slightly higher lysine content in the FB diet. The colour-flowered faba beans had a condensed tannins content of 406 ± 39 mg/100g.

Table 6. The analysed chemical compositions (g/kg) of the experimental diets

	Trial 1			Trial 2		
	SM	CBP	RSM	SM	RSM	FB
Crude protein	140	131	140	126	134	136
Lysine	8.3	8.6	8.4	8.2	8.9	9.0
Threonine	5.6	5.3	5.6	5.3	5.7	5.3
Methionine+cysteine	5.1	5.0	5.6	4.7	5.2	5.1
Tryptophan	1.89	1.80	1.87	1.65	1.85	1.71
Calcium	5.9	6.1	6.0	5.5	5.5	5.8
Phosphorus	4.40	5.4	4.65	4.55	4.70	4.80

Three pigs in Trial 1 and five in Trial 2 died or were euthanised due to illness unrelated to the study. Daily weight gain was consistently high (986 g/day) and no significant differences could be found between the different treatments neither in Trial 1 nor in Trial 2 (Table 7). The feed conversion ratio and the carcass composition were also unaffected of the protein feedstuff. The frequency of tail-biting recorded at slaughter did not differ between treatments (P>0.50) and was on average 3.2% (11 out of 345 pigs).

Table 7. Effects of experimental diets on performance in experiment 2

	Trial 1					Trial 2			
	SBM	CBP	RSM	CBP+ RSM	P-value	SBM	FB	FB+ RSM	P-value
No. of pigs	52	50	52	51		48	49	48	
Initial weight, kg	26.6	26.7	27.2	26.1	0.588	26.0	26.5	26.4	0.825
Final weight, kg	114.6	117.0	118.2	116.5	0.116	116.4	117.5	116.1	0.609
Daily weight gain, g	970	988	981	994	0.680	991	997	980	0.516
Feed conversion, MJ NE/kg growth	25.4	24.4	24.8	24.8	0.257	24.7	24.9	24.7	0.977
Feed intake, MJ NE/day	24.6	24.1	24.3	24.6	0.506	24.4	25.0	24.4	0.692
Lean meat, %	59.9	59.2	59.2	59.3	0.225	59.0	59.6	59.4	0.364
Lean meat growth, g/day	442	438	442	445	0.906	442	451	446	0549

Data are presented as least square means.

Discussion

Correct balancing of protein and amino acids (AA) in pig diets are important for performance, pig health, economy and nitrogen emission. In the present experiment, low lysine and protein diets were single fed to growing-finishing pigs in the intention to minimise the use of soya bean meal and increase the amount of cereal and locally produced protein feedstuffs in the diet. The experimental diets were formulated with regard to the content of lysine, threonine, methionine, cystine and tryptophan, the same amino acids that are formulated for in the feed industry. The present Swedish recommendation for lysine to slaughter pigs is given in an interval (Göransson *et al*., 2012) and the other AA and crude protein are optimised in relation to lysine.

As the AA requirements are higher at an early than at a late stage of growth, phase feeding is a common recommendation. Slaughter pigs are raised in pens with a number of individuals, varying in weight, and therefore it is impossible to total adapt the needs of amino acids on individual basis. To secure the EEA supply of lighter pigs the levels are higher in practical use than the recommendations. However, it is known that pigs have a capacity of growing compensatory after a period of restricted supply of nutrients. This experiment was designed to answer if the pigs grow compensatory when initially supplied with low amounts of protein and amino acids. Our results demonstrate that modern fast growing pigs totally compensated during the end of the production for an initial low amino acid and protein supply. Contrary, to Fabian *et al*. (2002 and 2004), and Reynolds and O'Doherty, (2006) we did not find any improved feed conversion ratio during the entire raising period for single fed pigs compared to phase fed pigs. From a practical point of view one feed during the entire raising period will simplify feed manufacturing and feed handling at the farm.

Decreasing the crude protein level from 15.5 to 13.8 g SID/g SID lysine only slightly affected the performance. Daily weight gain and feed conversion ratio were impaired with approximately 3%, whereas lean meat content was unaffected. At this low protein level the calculated valine:lysine ratio in our study was 0.61 compared to the recommended level of 0.67 (Göransson *et al*., 2012; Tybrik *et al*., 2015). Consequently, the question arose whether L-valine should be introduced when formulating low crude protein cereal based diets. In a cereal-soya bean meal diet a reduction in protein content to 13.8 from the recommended level of 15.5 will result in 50% less inclusion of soya bean meal and the nitrogen output from the pig will decrease with approximately 25% (calculated from Vils, 2007). Implementing this in practical slaughter pig production excludes the need of diets with high protein content in the early stage of the growing phase resulting in reduced nitrogen emission.

Low lysine level did neither affect the growth from start of the study to slaughter nor the carcass composition, whereas feed efficiency was marginally decreased. No interactions were found between level of lysine and crude protein, which means that it is relevant to use the same relation between protein and lysine irrespective of the dietary lysine content. As the need of amino acids is related to the weight of the pig, it could be expected that the performance of pigs with a low initial live weight should be affected by low amino acid supply. This was not the case, which indicates that it would be possible to decrease the amino acid contents of the diet even more.

In our study, the vaccinated male pigs grew faster than the females. However, it must be underlined that the pigs were raised in mixed pens. Hence, it is not possible to find out whether the difference in growth rate was due to a higher feed intake or a better feed efficiency. Nevertheless, it is interesting to notify that the daily growth of vaccinated male pigs was not affected by the crude protein content of the diet.

When designing experiments with different protein feedstuffs the level of inclusion is decided by the protein content of the main ingredient, most often being cereals, and the demands for dietary levels of crude protein and amino acids. Other factors affecting the inclusion level are the composition of the protein feedstuff and the applied feeding plan in terms of phase or single feeding. High inclusion of feedstuffs such as beans, peas or products from rapeseed, increases the risk of negative effects on the performance due to ANF.

Based on results from our first experiment it was decided to apply single feeding, secondly to use a feed with a low lysine level (0.78 g/MJ NE) and thirdly, to use a crude protein:lysine ratio of 14.5 (g SID crude protein/g SID lysine), which is below the Swedish recommendation

(Göransson *et al*., 2012). The amino acid contents in our experimental diets were lower than those in experiments published by other authors such as Partanen *et al*., 2003, Ziljstra *et al.*, 2008 and Smit *et al.*, 2014. Accordingly, the inclusion rates of protein feedstuffs in this experiment were relatively low. Despite the low levels of lysine and protein, the pigs performed very well and there were no differences in performance between treatments with different protein raw materials. Anti-nutritional factors in faba beans vary a lot between varieties. The faba beans used in this experiment were according to an analysis of condensed tannins (406 ± 39 mg/100g faba beans) a mixture of commercial batches of colour-flowered crop. Cereal by-products, especially dry distillers grains with solubles (DDGS), may be important protein feedstuffs in future pig production. The results from our experiment fully support the possibility of substituting soya bean meal and rapeseed meal by cereal protein in growing-finishing pig diets. Other researchers have reported somewhat diverging results. Thacker (2012) successively exchanged rapeseed meal with up to 20% of DDGS from wheat in growing-finishing pig diets, and found somewhat decreased growth and feed conversion. Widyaratne and Ziljstra (2007) included 25% DDGS from corn or wheat in slaughter pig diets without any effect on feed conversion but with somewhat lower feed intake and weight gain. Tofuko *et al.* (2016) reported no effect of including 10% wheat DDGS in a corn soya bean diet on growing-finishing pig performance.

Growth models request relevant basic data and most important is providing as correct feed conversion figures as possible. Feed conversion is affected by the weight of the pig and the relation between these parameters is therefore important to know. All data from our experiments have been used for calculation such an expression. The equations were as follows: MJ NE per kg weight gain = 18.44 + (0.05 x kg live weight) from start to 60 kg and 12.00 + (0.18 x kg live weight) from 60 kg to slaughter. The regression coefficients are close to that calculated by Sigfridson at Lantmännen (Sigfridson, personal communication).

Conclusion

The results from this project demonstrate the possibility of using single feed with low lysine and protein content to high performing and healthy pigs without affecting their performance. This will result in a higher use and value for cereals and domestic protein feedstuffs. Furthermore, the nitrogen output from the pig will decrease.

References

Report with references: see
http://www.slu.se/globalassets/ew/org/inst/huv/dokument/slutrapporthuv.pdf