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Utilisation of reactive lysine from meat and bone meals of different ash content by growing-finishing pigs

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A growth experiment was conducted using 50 pigs (25–100 kg) to evaluate the use of meat and bone meals of different ash content as a substitute for soyabean meal (SBM) for growing pigs and the potential of 1-fluoro-2,4-dinitrobenzene (FDNB) reactive lysine in diet formulation. The control diet consisted of barley and SBM. For test diets, either 33 or 67% of SBM was replaced with meat and bone meal of low (ML, 205 g ash/kg) or high (MH, 349 g ash/kg) ash content. SBM, ML33, ML67, MH33 and MH67 diets contained 7.8, 7.8, 8.2, 7.8 and 7.9 g FDNB-reactive lysine/feed unit (feed unit is equivalent to 9.3 MJ NE), respectively. For these diets, average daily live weight gains (ADG) were 859, 830, 805, 854 and 813 g/d with feed conversion ratios of 2.25, 2.40, 2.41, 2.31 and 2.44 feed units/kg, respectively. Pigs fed the SBM diet grew faster ($P<0.01$) and utilised feed more efficiently ($P<0.001$) than those offered ML and MH diets. The ADG decreased ($P<0.001$) with increasing meat and bone meal dietary inclusion. These results indicate that FDNB-reactive lysine is unsuitable for diet formulation as it may be incompletely absorbed. Faecal digestibilities of nutrients in the experimental diets were determined at live weights of 30, 44, 64 and 85 kg, respectively. Mean digestibility of crude protein (CP) was 74, 74, 68, 75 and 72%, while that of crude fat (CF) was 44, 55, 51, 48 and 41%, for SBM, ML33, ML67, MH33 and MH67 diets, respectively. Faecal digestibilities of CP and CF increased with live weight, with the largest increase being observed between 44 and 65 kg. Increased replacement of SBM with ML or MH increased back fat oleic acid content ($P<0.01$), decreased back fat firmness ($P<0.05$) but had little influence on palatability.

Key words: animal by-products, carcass quality, fatty acids, performance

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Introduction

Meat and bone meal is considered to be a good source of supplemental protein, calcium and phosphorus and is commonly used at low levels in commercial pig diets. However, growth rates and efficiency of feed utilisation are often reduced when increasing levels of dietary soyabean meal are replaced with meat and bone meal (Evans and Leibholz 1979, Cromwell et al. 1991). Impaired performance may result from reduced quality of dietary protein, excessive mineral intake or depressed diet palatability.

The quality of protein in meat and bone meal is influenced by the raw materials used and the processing methods and conditions (temperature, pressure and duration of heating) applied (Batterham et al. 1986a, 1986b, Donkoh et al. 1994). Protein of soft offal is typically highly digestible and has a more desirable amino acid profile than that of bone or connective tissue. However, application of heat causes a number of reactions within the protein structure. This results in digestibility and availability being reduced, and can lead to amino acids in meat and bone meal being destroyed (Batterham et al. 1986a, 1986b). Lysine is the most sensitive amino acid to heat damage, but other amino acids, e.g., methionine, cystine and tryptophan are also susceptible (Papadopoulos 1989).

It is generally accepted that the ileal amino acid digestibility assay provides an accurate estimate of lysine availability for unheated feedstuffs, while for heated protein sources it can lead to overestimates (Moughan et al. 1991, Batterham 1992). Overestimates can arise during the acid hydrolysis step of the conventional amino acid analysis causing some of the heat modified residues reverting back to lysine. While modified lysine residues may also be partially absorbed from the tract they are of little or no nutritional value to the pig. In the case of heated protein sources, the accuracy of diet formulation can be improved by using lysine availability determined by the slope-ratio assay (Batterham 1992). However, this method is slow and expensive, and values of availability may vary depending upon adopted response criteria (Leibholz 1992). Therefore, alternative methods are needed for routine evaluation of lysine availability in feeds of highly variable composition, such as meat and bone meal.

One approach is to assess availability by chemical analysis. In the case of lysine, residues with an ε-amino group free to react with chemical reagents are practically the most important source of available lysine. Carpenter (1960) has developed a method where following reaction with 1-fluoro-2,4-dinitrobenzene (FDNB), and subsequent acid hydrolysis, ε-fluoro-dinitrophenyl lysine (reactive lysine) is assessed. Despite some disadvantages, the method is still among the most useful in practice, because it allows large ranges of potential protein heat damage to be assessed (Hurrell and Carpenter 1974).

Meat and bone meal fat content can vary from a few grams to over 150 g/kg, depending on the method of fat separation (mechanical or solvent extraction). Eating quality and fatty acid composition of pork are sensitive to changes in the quantity and quality of dietary fat (Miller et al. 1990, Madsen et al. 1992). High levels of dietary animal fat increase the content of oleic acid in body fat (Mortensen et al. 1983) which may have a negative influence on fat firmness (Madsen et al. 1992). Consequantly, high levels of meat and bone meal in a diet can have undesirable effects on the technical and eating quality of pork.

The aim of this study was to evaluate two meat and bone meals of different ash content as a protein source for growing pigs and the use of FDNB-reactive lysine in diet formulation. Apparent faecal digestibilities of dietary nutrients were determined to allow net energy supply from the experimental diets to be estimated. Since the meat and bone meals studied had a relatively high fat content, the sensory characteristics of meat and adipose fatty acid profile were also assessed.

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Material and methods

Animals, diets and measurements

A performance study was conducted using 50 pigs of Finnish Landrace, Large White or crossbred origin (20:20:10) using a randomised complete block design. The initial live weight of the pigs was approximately 25 kg. A block was formed from five pigs of the same sex and litter origin. Within a block, pigs were randomly assigned to five dietary treatments. Pigs were housed individually in concrete floor pens. They were weighed in the beginning of weeks 1, 3, 6, 9 and 12 of the experiment and then weekly until they reached the minimum slaughter weight of 98 kg or had been in the experiment for 15 weeks.

Two meat and bone meals were manufactured in a traditional batch dry rendering system with approximately a two hour cooking cycle and sterilisation under pressure at about 125°C for 20–30 minutes. Fat was removed mechanically after rendering and meals were ground. The raw material consisted of cattle and swine offal and bones in different proportions, as indicated by the meal ash content. Meals with low and high ash content (Table 1) were designated as ML (205 g ash/kg) and MH (349 g ash/kg), respectively.

The control diet consisted of barley and soyabean meal (SBM). In the other four diets, either 33 or 67% of SBM was replaced with an equal amount of digestible crude protein derived from ML or MH (Table 2). The diets were formulated to have an equal amount of FDNB-reactive lysine per feed unit with the addition of L-lysine-HCl when required. The net energy content of ingredients was calculated using digestibility coefficients determined in previous studies for barley (Partanen et al. 1992), SBM and similar meat and bone meals (Partanen 1994). Dietary content of threonine, methionine and cystine, minerals and vitamins were calculated to satisfy the Finnish feeding recommendations (Salo et al. 1990). Pigs were fed twice daily according to a restricted feeding scale (1.0–2.8 feed units/d). Daily feed allowance was increased by 0.2 feed units/week in the beginning and by 0.1 feed units/week after week nine of the experiment.

Table 1. Chemical composition of barley, soyabean and meat and bone meals (g/kg).

	Barley	Soyabean meal	Low ash meat and bone meal	High ash meat and bone meal
Dry matter	883	887	984	974
Crude protein	120	420	534	449
Crude fat	20	32	175	159
Ash	21	55	205	349
Lysine	4.3	26.4	25.6	18.4
FDNB-lysine	4.1	23.1	19.7	15.7
Threonine	4.0	16.4	18.7	13.0
Isoleucine	4.0	18.5	16.5	11.2
Leucine	8.0	31.9	32.0	22.5
Valine	5.6	20.1	23.5	17.1
Phenylalanine	5.9	20.6	18.1	13.5
Tyrosine	2.9	13.4	12.8	8.5
Histidine	2.8	11.3	10.1	7.2

Faecal digestibilities of nutrients and energy were determined using acid insoluble ash (AIA) as a marker. Grab samples were collected after morning feeding from three randomly selected blocks of barrows for five days during weeks 3, 6, 9 and 12 of the experiment. During collection periods, no bedding was used and the pens were cleaned prior to morning feeding. Only the top part of faeces was collected from the floor immediately after defecation. Determined digestibility coefficients were used to recalculated dietary net energy supply according to Tuori et al. (1995), with one feed unit being equal to 9.3 MJ NE.

Pigs were slaughtered at a commercial slaughter house and cold carcass weight was measured after overnight chilling. The left half of the cold carcass was partitioned into valuable cuts (fore-end and shoulder, loin, and ham) which were dissected into lean (including bones) and fat (including skin) to determine the proportion of lean in the valuable cuts and whole car-

Table 2. Formulation and chemical composition of experimental diets (g/kg) containing soyabean or meat and bone meal.

Protein source	SBM	ML		MH	
Substitution level, %		33	67	33	67
Ingredient composition:					
Barley	808.8	808.8	808.8	808.8	808.8
Barley starch	–	14.0	27.4	19.5	23.3
Soyabean meal	150.0	100.0	50.0	100.0	50.0
Low ash meat and bone meal	–	47.0	94.0	–	–
High ash meat and bone meal	–	–	–	52.5	105.0
L-lysine-HCl	0.6	1.1	1.6	1.1	1.4
DL-methionine	2.1	2.1	2.2	2.1	2.0
Calcium carbonate	9.0	8.0	7.0	6.0	–
Monocalcium phosphate	18.5	9.0	–	–	–
Trace element premix[1]	2.0	2.0	2.0	2.0	2.0
Vitamin premix[2]	5.0	5.0	5.0	5.0	5.0
NaCl	4.0	3.0	2.0	3.0	2.5
Chemical composition:					
Dry matter	885	887	889	883	889
Crude protein	156	160	162	159	159
Crude fat	27	34	41	34	41
Crude fibre	49	45	47	45	40
Ash	49	48	48	48	59
Calcium	8.8	9.4	10.7	10.2	15.2
Phosphorus	7.1	6.7	6.4	6.5	9.4
Lysine[3]	7.9	8.2	8.5	8.0	7.8
FDNB-lysine[3]	7.3	7.4	7.6	7.3	7.2
Methionine+cystine[3]	6.4	6.5	6.8	6.5	6.5
Threonine[3]	5.7	5.8	5.8	5.6	5.4
Gross energy, MJ/kg	16.2	16.5	16.7	16.4	16.4
Net energy, FU/kg[4]	0.93	0.95	0.93	0.94	0.91

SBM = soyabean meal; ML = low ash meat and bone meal; MH = high ash meat and bone meal

[1] Composition per kg diet: 5000 IU vitamin A, 750 IU vitamin D_3, 15 mg vitamin E, 25 mg vitamin C, 0.25 mg vitamin K, 1 mg thiamine, 2.5 mg riboflavin, 4 mg pyridoxine, 0.015 mg vitamin B_{12}, 5 mg nicotinic acid, and 5 mg pantothenic acid.

[2] Composition per kg diet: 26 mg Fe, 92 mg Zn, 26 mg Mn, 26 mg Cu, and 0.12 mg Se.

[3] Calculated from ingredient amino acid composition, except for methionine+cystine which were based on published values (Partanen 1994).

[4] Calculated according to Tuori et al. (1995) based on measured digestibility coefficients.

cass. About 100 g of back fat and 100–150 g meat were taken from the loin posterior to the last rib from 6 randomly selected blocks (3 gilts, 3 barrows) for fatty acid analysis and organoleptic grading, respectively. Samples were frozen prior to analysis. Few samples were lost due to technical problems.

Chemical analyses and organoleptic grading

Chemical composition of feed components, feeds and faeces was determined according to standard AOAC methods (1984). Crude fat was deter-

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mined after hydrolysis in 4 M HCl. The amino acid composition of feed components was analysed by ion-exchange chromatography with post-column *O*-phthalaldehyde detection. Before analysis, samples were hydrolysed in 6 M HCl for 22 h at 110°C. FDNB-reactive lysine was measured according to Carpenter (1960). Dietary amino acid composition was calculated from that of its components. Since methionine and cystine were not determined, values reported by Partanen (1994) were used in the calculations. Phosphorus in feeds was determined by colorimetry (Tayssky and Shorr 1953) and calcium was measured by atomic absorption spectroscopy. AIA was measured according to Van Keulen and Young (1977).

Fat was extracted from feeds with methanol and chloroform (Karow et al. 1984), esterified with hexane, sodium methoxide and calcium chloride and analysed by gas chromatography. In order to analyse the fatty acid profile of adipose tissue, skin was removed from a 100 g sample of back fat. After grinding and melting (80°C), fatty acids were saponified with 0.5 M KOH-methanol solution and esterified with BF_3-methanol reagent. Methyl esters of fatty acids were extracted with hexane and analysed by gas chromatogaraphy. The values are given as percentages of total fatty acids. All analyses were performed in duplicate.

For organoleptic evaluation, samples of *musculus longissimus dorsi* were thawed and fried as described by Partanen et al. (1992). A trained test panel of three to five members graded fried samples for tenderness, juiciness and flavour by using a scale of 1 to 7, with 7 being the highest and 1 the poorest grade.

Statistical analyses

Data were analysed by the GLM procedure of SAS (1985). Performance and carcass data were subjected to a least-squares analysis of variance (Snedecor and Cochran 1989) using the model:

$$Y_{ij} = \mu + T_i + B_j + \varepsilon_{ij},$$

where T_i and B_j are the effects of treatment i and block j, respectively, and ε_{ij} is the error term. A split- plot design was applied for the statistical analysis of digestibility data using the model:

$$Y_{ijkl} = \mu + T_i + B_j + \varepsilon_{ij} + W_k + (W*T)_{ik} + (W*B)_{jk} + \varepsilon_{ijkl},$$

where T_i, B_i and W_k are the effects of treatment i, block j and week of sampling k, respectively, and ε_{ij} is the main plot error and ε_{ijkl} the sub-plot error. Four orthogonal contrasts were formed to allow the following comparisons: C1 = SBM vs. ML and MH diets, C2 = 33 vs. 67% of SBM replaced with ML or MH, C3 = ML vs. MH diets, and C4 = interaction C2 x C3. Only contrasts which are statistically significant ($P<0.05$) are presented in the tables.

Results

The chemical composition of the main dietary ingredients is shown in Table 1. The proportion of FDNB-reactive lysine of total lysine was 88, 77 and 85% for SBM, ML and MH, respectively. Chemical composition of the diets is shown in Table 2. SBM, ML33, ML67, MH33 and MH67 diets contained 7.8, 7.8, 8.2, 7.8 and 7.9 g FDNB-reactive lysine/feed unit, respectively.

One pig in treatment MH67 was removed from the experiment due to a bleeding ulcer. The pig ate and grew well for the first 12 weeks of the experiment. Consequently, performance data of weeks 1–12 are included in the calculations. All other pigs remained in good health throughout the study.

Faecal digestibilities of organic matter, crude protein (CP) and crude fat (CF) of the experimental diets are given in Table 3. CP digestibility decreased with increasing inclusion of meat and bone meal ($P<0.01$) and was lower in ML than MH diets ($P<0.05$). CF digestibility was lower in MH than ML diets ($P<0.01$) and tended to decrease with increasing level of meat and

Table 3. Apparent faecal digestibilities (%) of nutrients in diets containing soyabean and meat and bone meal.

Protein source	SBM	ML		MH			Significance[1]			
Substitution level, %		33	67	33	67	SEM	Wk	C1	C2	C3
Organic matter (mean)	81.3	81.4	79.2	81.4	79.4	0.21	***	*	***	
week 3	80.1	80.1	77.8	80.6	79.0	0.42				
week 6	80.3	80.7	78.6	80.5	78.1	0.42				
week 9	82.1	83.1	80.1	82.1	79.5	0.42				
week 12	82.6	81.8	80.5	82.3	80.7	0.42				
Crude protein (mean)	74.2	74.2	68.4	75.3	72.1	0.66	***		**	*
week 3	70.9	70.9	62.7	72.5	70.0	1.31				
week 6	70.7	72.4	66.1	73.0	69.5	1.31				
week 9	76.8	77.1	71.4	77.3	73.3	1.31				
week 12	78.4	76.3	73.3	78.5	75.4	1.31				
Crude fat (mean)	44.1	54.5	51.1	47.6	41.2	1.05	*			**
week 3	43.2	53.2	47.7	46.9	40.6	2.10				
week 6	42.2	53.7	51.9	46.7	35.4	2.10				
week 9	46.5	58.9	52.4	48.8	44.1	2.10				
week 12	44.6	52.3	52.3	48.2	44.5	2.10				

SBM = soyabean meal; ML = low ash meat and bone meal; MH = high ash meat and bone meal

[1] Wk: effect of week; Contrasts: C1: SBM vs. ML and MH diets, C2: 33 vs. 67% of SBM replaced with ML or MH; C3: ML vs. MH diets; Significance: *** (P<0.001), ** (P<0.01), * (P<0.05).

bone meal in the diet (P=0.06). Mean pig live weight at the beginning of weeks 3, 6, 9 and 12, when the faecal digestibilities were determined, was 30, 44, 64 and 85 kg, respectively. Both linear and cubic effects of time were significant for digestibility of all nutrients, except ash. The largest increase in nutrient digestibilities was observed between live weights of 44 and 65 kg.

Pigs fed SBM diet grew faster (P<0.01), utilised feed more efficiently (P<0.01) and tended to have a higher meat percentage in carcass (P=0.08) compared with pigs fed ML and MH diets (Table 4). Average daily live weight gain (ADG) was depressed (P<0.001) and the feed conversion ratio (FCR) tended to improve (P=0.07) with increasing replacement of SBM with ML or MH. A slightly lower (P=0.09) ADG was observed for ML than MH diets, but there were no differences in FCR. No significant differences were observed in back or side fat thickness between treatments.

Fatty acid profile of back fat was clearly influenced by dietary treatment (Table 5). The content of oleic acid (C18:1) increased with increasing level of meat and bone meal in the diet (P<0.05), whereas that of linoleic and linolenic acid decreased (P<0.001 and P<0.01, respectively). The total content of saturated fatty acids was not influenced by dietary treatments. In contrast monounsaturated fatty acids increased (P<0.01) and polyunsaturated decreased (P<0.001) with increasing substitution of SBM with ML or MH. Back fat became softer (P<0.05) with increasing dietary inclusion of meat and bone meal. Meat flavour and juiciness were not influenced by dietary treatments, however meat became more tender (P<0.05) with increasing level of meat and bone meal in a diet.

Discussion

The meat and bone meals used in this study were manufactured in a batch dry rendering system. Poorer performance of pigs fed ML than MH diets suggests that the batch dry rendering re-

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Table 4. Performance and carcass characteristics of pigs fed diets containing soyabean and meat and bone meal.

Protein source	SBM	ML		MH			Significance[1]	
Substitution level, %		33	67	33	67	SEM	C1	C2
Number of pigs	10	10	10	10	10[2]			
Initial weight, kg	24.8	24.7	24.7	24.4	24.7	0.53		
Final weight, kg	98.7	99.1	98.4	99.2	99.2	0.87		
Days in trial	86	90	92	88	92	1.5	*	*
Daily gain, g	859	830	805	854	813	9.1	**	***
Feed, kg/pig	188	197	199	192	208	4.0	*	*
Feed, FU/pig	166	179	178	173	181	3.5	**	
FCR, FU/kg	2.25	2.40	2.41	2.31	2.44	0.037	**	
Carcass weight, kg	72.3	72.9	72.7	73.2	74.2	0.59		
Loss at slaughter, %	26.8	26.5	26.2	26.2	26.1	0.26		
Lean in valuable cuts, %	83.0	82.9	82.0	82.0	82.4	0.46		
Lean in carcass, %	56.2	55.8	55.4	55.0	55.5	0.39		
Back fat, mm	23.9	24.3	24.7	24.1	25.0	0.73		
Side fat, mm	15.8	15.3	16.4	17.4	15.9	0.73		
Firmness of fat[3]	13.7	13.8	13.4	14.0	13.5	0.18		*

SBM = soyabean meal; ML = low ash meat and bone meal; MH = high ash meat and bone meal; SEM = standard error of mean; FCR = feed conversion ratio.

[1] Contrasts: C1: SBM vs. ML and MH diets, C2: 33 vs. 67% of SBM replaced with ML or MH; Significance: *** ($P<0.001$), ** ($P<0.01$), * ($P<0.05$).

[2] Only 9 observations for carcass characteristics. The SEM value is 1.067 times the value given in the table.

[3] Score 9–15.

sulted in a more severe heat damage to lysine in meal containing a higher proportion of soft offal. Soft offal protein appears to be more susceptible to heat damage than that of bones and other structural tissues and perhaps different processing conditions should be applied to different raw materials. This is consistent with our previous conclusions (Partanen 1994), where significantly higher nitrogen retention was observed when pigs were fed diets with meat and bone meal of high (319 g/kg) compared to low ash content (204 g/kg). Haugen et al. (1985) have also reported that ileal digestibility of soft offal was reduced by increasing processing temperature, while that of hard structural offal was not affected by higher temperatures.

In this study, lysine was the first limiting amino acid in the diets (Wang and Fuller 1989). Since barley-based diets were used the tryptophan content did not become limiting, as it can in the case of corn-meat and bone meal diets (Cromwell et al. 1991). Lysine availability was estimated by chemical determination of the proportion of FDNB-reactive lysine of total lysine, and the diets were formulated to be similar in FDNB-reactive lysine content, assuming that FDNB-reactive lysine was equally digested and absorbed between protein feedstuffs. However, differences in the performance of pigs between SBM, ML and MH diets indicates that FDNB-reactive lysine is unsuitable in diet formulation, possibly due to differences in the digestibility of reactive lysine in the protein sources used. It seems that the reactive lysine in ML is less digestible than that in MH. Recent results of Moughan et al. (1996), and Moughan and Rutherfurd (1996) indicate that the digestibility of reactive lysine from heat-treated protein is variable and incomplete.

Severe and prolonged heat treatment, such as

Table 5. Dietary and back fat fatty acid composition (%, w/w) and organoleptic quality of pork.

Protein source	SBM	ML		MH			Significance[2]		
Substitution level, %		33	67	33	67	SEM[1]	C1	C2	C3
Diets									
C16:0	16.4	20.6	22.2	20.1	22.3				
C18:0	2.3	9.0	12.5	7.1	10.8				
C18:1	14.5	21.3	24.8	22.5	29.0				
C18:2	59.1	43.6	35.9	44.5	33.6				
C18:3	7.8	5.6	4.5	5.9	4.4				
Back fat									
n	6	5	6	5	3				
C14:0	1.3	1.3	1.4	1.4	1.4	0.04			
C16:0	24.5	24.4	24.0	24.5	24.5	0.26			
C16:1	2.2	2.2	2.4	2.5	2.5	0.12			
C17:0	0.30	0.35	0.33	0.31	0.32	0.021			
C18:0	14.4	14.5	13.4	13.6	14.0	0.32			
C18:1	42.5	42.9	45.4	44.7	45.8	0.57	**	*	
C18:2	10.1	9.5	8.4	8.6	7.3	0.23	***	***	**
C18:3	1.05	0.95	0.80	0.81	0.71	0.03	***	**	**
C20:0	0.22	0.21	0.23	0.21	0.21	0.014			
C20:1	1.0	1.0	1.1	1.1	1.1	0.05			
C20:2	0.52	0.52	0.45	0.44	0.38	0.018	**	**	**
C20:4	0.23	0.24	0.25	0.22	0.23	0.017			
Saturated	40.8	40.7	39.4	40.0	40.4	0.36			
Monoenes	45.7	46.2	48.9	48.2	49.4	0.59	**	*	
Polyenes	11.9	11.2	9.9	10.1	8.6	0.26	***	***	**
Organoleptic quality[3]									
n	6	6	6	5	4				
Tenderness	4.5	3.3	4.6	3.9	4.2	0.24		*	
Juiciness	4.7	4.8	4.7	4.9	4.8	0.16			
Flavour	4.8	4.9	4.9	4.9	4.9	0.18			

SBM = soyabean meal; ML = low ash meat and bone meal; MH = high ash meat and bone meal; SEM = standard error of mean.

[1] The given SEM value is for treatments with 6 observations. In fatty acid composition, the given SEM value should be multiplied with 1.517 and 1.140 for treatments with 3 and 5 observations, and in organoleptic quality, with 1.176 and 1.119 for treatments with 4 and 5 observations, respectively.

[2] Contrasts: C1: SBM vs. ML and MH diets, C2: 33 vs. 67% of SBM replaced with ML or MH, C3: ML vs. MH diets; Significance: *** (P<0.001), ** (P<0.01), * (P<0.05).

[3] Score 1–7 (1=very poor, 7=very good).

rendering, is known to cause the formation of cross-linkages within protein molecules. In animal by-products, where the content of carbohydrates is negligible, the ε-amino group of lysine can form links with the carboxyl group of aspartate and glutamate or with the amide groups of glutamine and asparagine. Lysinoalanine and lanthionine cross-linkages may also be formed (Hurrell et al. 1976). Amino acid residues involved in cross linkages are not only unavailable to the animal, but these cross linkages may also prevent enzyme penetration or mask the sites of enzyme attack, leading to a reduction in the digestibility of free lysine residues and other amino acids (Papadopoulos 1989).

A part of the overestimation of lysine availa-

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bility by FDNB-method may be due to analytical method employed. In addition to the ε-amino group, the α-amino group from free lysine can also react with FDNB and will, therefore, result in an overestimation of reactive lysine (Moughan and Rutherfurd 1996).

When high levels of MBM are used in pig diets, mineral content, particularly calcium and phosphorus, tend to be high. Pigs can tolerate relatively high calcium and phosphorus levels, when their ratio is within certain limits. However, the high dietary mineral content may have a negative influence on the digestibility of fat and, therefore, the energy value of the diet (Jørgensen et al. 1992). The lower digestibility of CF observed in MH diets compared with ML diets is in agreement with earlier results, which demonstrated that in meat and bone meals, faecal CF digestibility decreases with increasing meal ash content (Just et al. 1982, Partanen 1994). The improved faecal digestibility of nutrients with increasing live weight is in agreement with earlier findings (Roth and Kirchgessner 1984).

Inclusion of meat and bone meal in a diet increased the dietary content of palmitic, stearic and oleic acids and decreased that of linoleic and linolenic acids. The changes in dietary fatty acid composition resulted in similar trends in fatty acid composition of back fat as the content of oleic acid increased and that of linoleic and linolenic acid decreased with increasing level of ML or MH in the diet. The back fat content of unsaturated fatty acids was not altered due to dietary treatment. Changes in fatty acid profile were also reflected in fat firmness as slightly softer back fat was observed with increasing level of ML or MH in a diet. Softening of back fat has been reported when increasing levels of animal fat have been fed to growing pigs (Mortensen et al. 1983). Saturated fatty acids (C12:0–C18:0) are known to have a positive influence, while monounsaturated (C16:1, C18:1) and particularly the polyunsaturated fatty acids (C18:2, C18:3) have a negative influence on the firmness of carcass fat tissues (Madsen et al. 1992). Feeding meat and bone meal to pigs had no negative influence on the eating quality of pork. Slightly improved tenderness with increasing level of ML or MH in a diet may be due to differences in the composition of growth between treatments, since a slower live weight gain is often involved with increased fat formation.

In conclusion, the results of this study indicate that lysine availability determined as FDNB-reactivity is inaccurate in diet formulation, probably due to differences in the absorption of reactive lysine between different feedstuffs. Reduced performance observed with meat and bone meal diets may also result from excessive dietary mineral intake. The high mineral level of a diet may reduce faecal digestibility of crude fat and therefore dietary energy value. Increasing the substitution of SBM with ML or MH increased back fat oleic acid content and decreased back fat firmness, but had little influence on the palatability of pork.

References

AOAC 1984. *Official methods of analysis.* Association of Official Analytical Chemists, Inc., Arlington, Virginia 1141 p.

Batterham, E.S. 1992. Availability and utilization of amino acids for growing pigs. *Nutrition Research Reviews* 5: 1–18.

– , Darnell, R.E., Herbert, L.S. & Major, E.J. 1986a. Effect of pressure and temperature on the availability of lysine in meat and bone meal as determined by slope ratio assays with growing pigs, rats and chicks and by chemical techniques. *British Journal of Nutrition* 55: 441–453.

– , Lowe, R.F., Darnell, R.E. & Major, E.J. 1986b. Availability of lysine in meat meal, meat and bone meal and blood meal as determined by the slope-ratio assay with growing pigs, rats and chicks and by chemical techniques. *British Journal of Nutrition* 55: 427–440.

Carpenter, K.J. 1960. The estimation of the available lysine in animal protein foods. *Biochemical Journal* 77: 604–610.

Cromwell, G.L., Stahly, T.S. & Moneque, H.J. 1991. Amino acid supplementation of meat meal in lysine-fortified, corn-based diets for growing-finishing pigs. *Journal of Animal Science* 69: 4898–4906.

Donkoh, A., Moughan, P.J. & Smith, W.C. 1994. True ileal digestibility of amino acids in meat and bone meal for the growing pig-application of a routine rat digestibility study. *Animal Feed Science and Technology* 49: 73–86.

Evans, D.F. & Leibhoz, J. 1979. Meat meal in the diet of the early-weaned pig. I. A comparison of meat meal and soya bean meal. *Animal Feed Science and Technology* 4: 33–42.

Haugen, E.W., Pettigrew, J.E., Cornelius, S.G. & Moser, R.L. 1985. Effects of meat meal manufacturing variations on amino acid bioavailability in pigs. *Journal of Animal Science* 61 (Supplement 1): 100.

Hurrell, R.F. & Carpenter, K.J. 1974. Mechanisms of heat damage in proteins. 4. Reactive lysine content of heat-damaged materials as measured in different ways. *British Journal of Nutrition* 32: 589–604.

– , Carpenter, K.J., Sinclair, W.J., Otterburn, M.S. & Asquith, R.S. 1976. Mechanisms of heat damage in proteins. 7. The significance of lysine-containing isopeptides and of lanthionine in heated proteins. *British Journal of Nutrition* 35: 383–395.

Jørgensen, H., Jakobsen, K. & Eggum., B.O. 1992. The influence of different protein, fat and mineral levels on the digestibility of fat and fatty acids measured at the terminal ileum and in faeces of growing pigs. *Acta Agriculturæ Scandinavica, Section A, Animal Science* 42: 177–184.

Just, A., Fernández, J.A. & Jørgensen, H. 1982. Kødbenmels værdi til svin. 525. *Beretning fra Statens Husdyrbrugs forsøg*, København 52 p.

Karow, R.S., Forsgerg, R.A. & Peterson, D.M. 1984. A comparison of rapid oat-lipid extraction procedures in term of acid profile. *Cereal Chemistry* 61: 196–197.

Leibholz, J. 1992. The availability of lysine in diets for pigs: comparative methodology. *British Journal of Nutrition* 67: 401–410.

Madsen, A., Jakobsen, K. & Mortensen, H.P. 1992. Influence of dietary fat on carcass fat quality in pigs. A review. *Acta Agriculturæ Scandinavica* 42: 220–225.

Miller, M.F., Shackelford, S.D., Hayden, K.D. & Reagan, J.O. 1990. Determination of the alteration in fatty acid profiles, sensory chracteristics and carcass traits of swine fed elevated levels of monounsaturated fats in the diet. *Journal of Animal Science* 68: 1624–1631.

Mortensen, H.P., Madsen, A., Bejerholm, C. & Barton, P. 1983. Fedt og fedtsyrer til slaktesvin. 540. *Beretning fra Statens Husdyrforsøg*, København 48 p.

Moughan, P.J., Gall, M.P.J. & Rutherfurd, S.M. 1996. Absorption of lysine and deoxyketosyllysine in an early-Maillard browned casein by the growing pig. *Journal of Agricultural and Food Chemistry* 44: 1520–1525.

– & Rutherfurd, S.M. 1996. A new method for determining digestible reactive lysine in foods. *Journal of Agricultural and Food Chemistry* 44: 2202–2209.

– , Smith, W.C., Pearson, G. & James, K.A.D. 1991. Assessment of apparent ileal lysine digestibility for use in diet formulation for the growing pig. *Animal Feed Science and Technology* 34: 95–109.

Papadopoulos, M.C. 1989. Effect of processing on high-protein feedstuffs: A review. *Biological Wastes* 29: 123–138.

Partanen, K. 1994. The effect of ash content on the nutritive value of meat and bone meal for growing pigs. *Acta Agriculturæ Scandinavica, Section A, Animal Science* 44: 152–159.

– , Alaviuhkola, T. & Näsi, M. 1992. Ensileged slaughter offal as a protein source for growing pigs. *Agricultural Science in Finland* 1: 547–558.

Roth, F.X. & Kirchgessner, M. 1984. Verdaulichkeit der Energie und Rohnährstoffe beim Schwein in Abhängigkeit von Fütterungsniveau und Lebendgewicht. *Zeitschrift für Tierphysiologie, Tierernährung und Futtermitelkunde* 51: 79–87.

Salo, M.-L., Tuori, M. & Kiiskinen, T. 1990. *Rehutaulukot ja ruokintanormit.* Yliopistopaino, Helsinki 70 p.

SAS 1985. *SAS User's Guide: Statistics.* 5th ed. SAS Institute, Inc., Cary, North Carolina 956 p.

Snedecor, G.W. & Cochran, W.G. 1989. *Statistical methods.* 8th ed. Iowa University Press, Ames, Iowa 503 p.

Tayssky, H.H. & Shorr, E. 1953. A microcolorimetric method for the determination of inorganic phosphorus. *Journal of Biological Chemistry* 202: 675–685.

Tuori, M., Kaustell, K., Valaja, J., Aimonen, E., Saarisalo, E. & Huhtanen, P. 1995. *Rehutaulukot ja ruokintasuositukset.* Yliopistopaino, Helsinki 99 p.

Van Keulen, J. & Young, A. 1977. Evaluation of acid-insoluble ash as a natural marker in ruminant digestibility studies. *Journal of Animal Science* 44: 282–287.

Wang, T.C. & Fuller, F. 1989. The optimum dietary amino acid pattern for growing pigs. 1. Experiments by amino acid deletion. *British Journal of Nutrition* 62: 77–89.

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SELOSTUS

Tuhkapitoisuuden vaikutus lihaluujauhon reaktiivisen lysiinin hyväksikäyttöön lihasioilla

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Kasvatuskokeessa selvitettiin, miten soijarouheen korvaaminen tuhkapitoisuudeltaan erilaisilla lihaluujauhoilla vaikuttaa sikojen tuotantotuloksiin ja teuraslaatuun, kun rehuseokset optimoitiin käyttökelpoisen lysiinin perusteella. Lysiinin käyttökelpoisuus määritettiin kemiallisesti 1-fluoro-2,4-dinitrobentseeni (FDNB) -menetelmällä. Tutkittavissa lihaluujauhoissa oli 205 ja 349 g tuhkaa/kg ja ne valmistettiin kuivasulatusmenetelmällä. Kokeessa oli mukana 50 sikaa, jotka jaettiin viiteen yhtä suureen ryhmään ja kasvatettiin yksilökarsinoissa 25 kilon alkupainosta noin 100 kilon loppupainoon. Kontrollina olleen ohra-soijarouheseoksen soijarouheen sulavasta raakavalkuaisesta korvattiin 33 tai 67% tuhkapitoisuudeltaan erilaisilla lihaluujauhoilla. Rehuseoksissa oli 7 g FDNB-reaktiivista lysiiniä/rehuyksikkö (ry). Rehuseosten kokonaissulavuudet määritettiin merkkiainemenetelmällä 3., 6., 9. ja 12. koeviikolla, jolloin siat painoivat 30, 44, 65 ja 85 kg elopainoa. Teurastuksen yhteydessä kyljysselästä otettiin näytteet silavan rasvahappokoostumuksen ja lihan aistinvaraisen laadun määrittämistä varten.

Sikojen päiväkasvu ja rehun hyväksikäyttö oli ohra-soijarouheruokinnalla parempi kuin lihaluujauhoruokinnoilla. Päiväkasvu hidastui suoraviivaisesti, kun lihaluujauhon osuus rehuseoksessa kasvoi. Siat kasvoivat matalatuhkaista lihaluujauhoa sisältäneillä ruokinnoilla hitaammin kuin runsastuhkaista lihaluujauhoa sisältävillä ruokinnoilla. Heikentyneiden tuotantotulosten perusteella FDNB-reaktiivinen lysiini yliarvioi lihaluujauhojen käyttökelpoisen lysiinin määrää soijarouheeseen verrattuna, mikä todennäköisesti johtui raaka-aineiden välisistä eroista reaktiivisen lysiinin imeytymisessä. Rehun kokonaissulavuus parani sikojen elopainon kasvaessa muutoksen ollessa suurin elopainovälillä 44–65 kg. Lihaluujauho muutti selkäsilavan rasvahappokoostumusta siten, että öljyhapon osuus rasvahapoista kasvoi selvästi. Muutos havaittiin myös silavan pehmenemisenä. Lihaluujauhoruokinnat eivät vaikuttaneet haitallisesti lihan syöntilaatuun.