THE EFFECT OF PRODUCTION SYSTEM, DIETARY PROTEIN LEVELS AND AMINO ACID SUPPLEMENTATION ON PERFORMANCE, CARCASS TRAITS AND MEAT QUALITY IN GROWING-FINISHING PIGS

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Summary. The objective of this study was to determine the effect of production system (two-stage and three–stage fattening) and a decrease in total protein levels in diets supplemented and not supplemented with lysine, methionine, threonine and tryptophan on fattening performance and carcass quality traits in growing-finishing pigs. The experimental materials comprised 45 young hybrid hogs (Polish Landrace x Polish Large White ♀) x Duroc ♂ allocated to two-stage and three-stage production systems, and further subdivided into three experimental groups. Irrespective of the production system, diet 1-C contained standard protein and amino acid (lysine, methionine, threonine and tryptophan), in diet 2 the levels of protein and amino acids were reduced by 15% relative to the standard levels, and diet 3, with a reduced total protein concentration, was supplemented with essential amino acids to the level of diet 1-C.

The results of this study indicate that in two-stage and three-stage production systems, pigs fed diets with standard total protein levels can have daily gains above 850 g and feed intake per kg body weight gain below 3.0 kg. In the two-stage system, a 15 % reduction in the total protein content of complete diets had no significant adverse effect on pig performance and carcass quality traits. The efficacy of low-protein diets was lower in the three-stage system than in the two-stage system - the growth rate of pigs decreased by 9.3% and feed consumption increased by 7.4%. The addition of lysine, methionine, threonine and tryptophan to low-protein diets improved pig performance, in particular in the three-stage production system. Diet supplementation with exogenous amino acids had no significant beneficial influence on carcass traits and meat quality.

Keywords: production system, dietary protein levels, amino acids, fattening performance, carcass traits, meat quality, growing-finishing pigs.

PENĖJIMO SISTEMOS, MITYBINIŲ BALTYMŲ KIEKIO IR AMINORŪGŠČIŲ ĮTAKA SUAUGUSIŲ KIAULIŲ SKERDENOS VERTEI IR MĖSOS KOKYBEI

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Santrauka. Tyrimų su kiaulėmis metu nustatyta II ir III fazės šėrimo sistemos bei sumažėjusių bendrųjų baltymų pašaruose (be lizino ir su lizinu, metioninu, treoninu, triptofanu) įtaka penėjimui, skerdenos vertei ir kiaulių mėsos kokybei. Tyrimai atlikti su 45 paršeliais (Lenkijos landrasai x Lenkijos didžioji baltoji ♀) x Diuroko veislių hibridais ♂ pagal II ir III fazės šėrimo sistemą. Gyvuliai suskirstyti į tris tiriamąsias grupes, po 7 ir 8 paršelius kiekvienoje. Nepriklausomai nuo šėrimo sistemos, pašaro 1-C sudėtyje buvo standartinis bendrųjų baltymų ir egzogeninių aminorūgščių (lizino, metionino, treonino ir triptofano) kiekis. II grupės pašare buvo 15 proc. mažiau bendrųjų baltymų ir egzogeninių aminorūgščių palyginti su standartu, o III grupės pašare sumažintą bendrųjų baltymų kiekį kompensavo egzogeninės aminorūgštys, kurių buvo kaip ir mišinyje 1-C. Tyrimų metu nustatyta, kad pagal II ir III fazės šėrimo sistemą (naudojant mišinį su standartiniu bendrųjų baltymų kiekiu) vidutinis prieaugis siekė 850 g per parą, o pašarų sąnaudos 1 kg kūno masės prieaugiui buvo mažesnis nei 3,0 kg. Kiaulių pašaruose (pagal dviejų fazių šėrimo sistemą) esančių bendrųjų baltymų sumažėjimas 15 proc. palyginti su standartu neigiamos įtakos penėjimosi rodikliams ir skerdenos kokybei neturėjo. III fazės kiaulių šėrimo sistemos pašarų mišinio (su sumažinta bendrųjų baltymų koncentracija) mitybinis efektyvumas buvo mažesnis, nei II fazės šėrimo sistemos. Nustatyta, kad paršelių augimo sparta sumažėjo 9,3 proc., o pašarų sąnaudos padidėjo 7,4 proc. Kiaulių pašaro mišiniai, papildyti lizinu, metioninu, treoninu ir triptofanu, padidino penėjimosi efektyvumą, ypač III fazės šėrimo sistemos. Tačiau nebuvo pastebėta ypač teigiama egzogeninių aminorūgščių įtaka skerdenos kokybei.

Raktažodžiai: penėjimo sistema, mitybinių baltymų kiekis, aminorūgštys, penėjimas, skerdenos vertė, mėsos kokybė, suaugusios kiaulės.

Introduction. In recent years, many attempts have been made to meet the exogenous amino acid requirements of pigs and to decrease the total protein content of diets, in order to reduce nitrogen emissions into the environment. The supplementation of pig diets with lysine – the main limiting amino acid – and with the other essential amino acids, methionine, threonine and tryptophan, may contribute to limiting the pollution from nitrogen excretion (Knabe, 1996). However, the effects of diets with a decreased protein content, supplemented with exogenous amino acids, on the fattening performance of pigs and pork quality have not been investigated in detail to date. The results of previous research are ambiguous and vary widely (Kerr et al., 1995; Tuitoek et al., 1997a,b, Figueroa et al., 2002; Garry et. al., 2007). There is also insufficient information regarding the impact of two- and three-stage production systems, adjusted to the production process or the growth rate of animals, on pig performance and the quality of meat from pigs fed diets with a decreased total protein content.

The objective of this study was to determine the effect of production system and a decrease in total protein levels in diets supplemented and not supplemented with lysine, methionine, threonine and tryptophan on fattening performance and carcass quality traits in growing-finishing pigs.

Materials and Methods. Own complete diets for growing-finishing pigs were formulated following the grinding of cereal grains and partial grinding of high-protein feed components. Rapeseed oil was used to balance the energy value or diets. The experimental design is presented in Table 1.

Table 1. **Experimental design**

Specification	Diets for growing-finishing pigs with different inclusion levels of protein and exogenous amino acids		
	Standard[1]/control[2]	-15% TP [3]	- 15% TP [3] + lys, met, thre, trp
Two-stage production system			
30–75 kg BW – grower diet	+	+	+
75–110 kg BW – finisher diet	+	+	+
Number of animals	7	7	7
Three-stage production system			
30–55 kg BW – grower I diet	+	+	+
55–80 kg BW – grower II diet	+	+	+
80–110 kg BW – finisher diet	+	+	+
Number of animals	8	8	8

Standard[1]-the levels of total protein and lysine in accordance with the current Pig Nutrient Requirements determined for daily weight gains of 800 g; Control[2] -only in the three-stage production system for grower diet II and finisher diet; TP[3]-total protein

Table 2. **Composition of complete grower and finisher diets with different levels of total protein and exogenous amino acids, fed to pigs in the two-stage production system,** %

Specification	Grower diet			Finisher diet		
	1-C[1]	2	3	1-C[1]	2	3
	standard	-15% TP [2]	-15% TP [2] + AA	standard	-15% TP [2]	-15% TP [2] + AA
Feed components, %						
Wheat	40.00	40.00	40.00	40.00	40.00	40.00
Barley	37.28	42.45	42.02	43.92	49.47	49.18
Soybean meal	15.00	9.00	9.00	6.00	-	-
Rapeseed meal „00''	5.00	5.00	5.00	8.00	8.00	8.00
Mineral feeds [3]	1.80	1.80	1.80	1.35	1.35	1.35
Lutamix	0.70	0.70	0.70	0.50	0.50	0.50
L-lysine	0.22	0.25	0.41	0.23	0.23	0.42
DL-methionine	-	-	0.15	-	-	0.04
L-threonine	-	-	0.09	-	-	0.08
DL-tryptophan	-	-	0.03	-	-	0.03
Rapeseed oil	-	0.80	0.80	-	0.40	0.40

1-C[1]-control group; TP[2] -total protein; Mineral feeds[3] -limestone (0.8/07%), 2-Ca phosphate (0.7/0.4%), fodder salt (0.3/0.25%)

Fattening performance. The experimental materials comprised 45 young hybrid hogs (Polish Landrace x Polish Large White ♀) x Duroc ♂, allocated to two- and three-stage production systems (Table 1). Fattening was carried out from 30 kg to 110 kg body weight. In the two-stage system, the pigs were divided into three experimental groups, each of seven animals. At the first stage of fattening (30 - 75 kg BW), the hogs were fed complete grower diets, and at the second stage (75 - 110 kg BW) they were offered finisher diets (Table 2). The nutritional value of diets was balanced in accordance with the Pig Nutrient Requirements (1993) determined for daily weight gains of 800 g. In the three-stage system, the pigs were divided into three experimental groups, each of eight animals. At the first stage of fattening (30 - 55 kg BW), the pigs were fed complete grower I diets, at the second stage (55 - 80 kg BW) they received grower II diets and at the third stage (80 - 110 kg BW) finisher diets (Table 3). Similarly as in the two-stage system, the nutritional value of experimental diets was balanced in accordance with the Pig Nutrient Requirements (1993) determined for daily weight gains of 800 g.

Table 3. **Composition of complete grower I, grower II and finisher diets with different levels of total protein and exogenous amino acids, fed to pigs in the three-stage production system,** %

Specification	Grower I diet			Grower II diet			Finisher diet		
	1-C[1]	2	3	1-C[1]	2	3	1-C[1]	2	3
	standard	- 15% TP[2]	- 15% TP[2] + AA	control	- 15% TP[2]	- 15% TP[2] + AA	control	- 15% TP[2]	- 15% TP[2] + AA
Feed components, %									
Wheat	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Barley	37.28	42.45	42.02	43.24	49.02	48.82	48.15	56.15	55.8
Soybean meal	15.00	9.00	9.00	9.00	3.00	3.00	-	-	-
Rapeseed meal „00''	5.00	5.00	5.00	5.00	5.00	5.00	10.00	2.00	2.00
Mineral feeds [3]	1.80	1.80	1.80	1.70	1.70	1.70	1.15	1.15	1.15
Lutamix	0.70	0.70	0.70	0.50	0.50	0.50	0.50	0.50	0.50
L-lysine	0.22	0.25	0.41	0.23	0.28	0.42	0.2	0.2	0.35
DL-methionine	-	-	0.15	-	-	0.04	-	-	0.06
L-threonine	-	-	0.09	-	-	0.09	-	-	0.11
DL-tryptophan	-	-	0.03	-	-	0.03	-	-	0.03
Rapeseed oil	-	0.80	0.80	0.30	0.40	0.40	-	-	-

1-C[1] -control group; [2] -see Table 1; Mineral feeds[3] -limestone (0.8/0.7/0.6%), 2-Ca phosphate (0.7/0.7/0.3%), fodder salt (0.3/0.3/0.25%)

All animals were kept in individual pens. Feed was served in friable form, and it was mixed with water at a 1:1 ratio prior to administration. Daily weight gains were estimated at successive stages of fattening. Feed conversion was determined based on the intake of feed, total protein and metabolizable energy per kg body weight gain.

Carcass quality parameters. At the completion of the feeding trial, all experimental animals were slaughtered and carcass quality traits were determined in both production systems. Carcass dressing percentage, carcass conformation and fatness (according to the EUROP classification system, Polish Standard PN-91/A-82001/A1) were determined immediately after slaughter. Samples of *m. longissimus dorsi* were collected from carcasses chilled for 24 hours at around 2-4^{o}C to analyze the chemical composition of meat, including the content of dry matter, crude ash, total protein and intramusclular fat. Pork quality was determined based on physicochemical and sensory properties, and shear force values. The physicochemical properties of meat included pH_{45} and pH_{24}, water-holding capacity and color parameters L*, a*, b*. The following sensory attributes of meat were evaluated: aroma, tenderness, juiciness and taste.

Chemical analysis. The nutrient content of feed raw materials and diets, and the chemical composition of meat were determined by standard methods (Official methods, 1990). The amino acid composition of protein in feed components was determined using the Biochrom 20 Plus analyzer. Meat color (L - lightness, a - redness, b - yellowness) was evaluated in the CIELAB system, by the reflectance method, using the Miniscan XE Plus color measuring instrument (HunterLab). The water-holding capacity of pork was estimated by the GRAU and HAMM method (1953) modified by Van Oeckel et al. (1995), sensory attributes were evaluated according to Polish Standard PN-ISO 4121 (1998), and shear force values were measured as described by Honikel (1998).

Statistical analysis. The obtained results were verified statistically by a one-factor analysis of variance (ANOVA). The statistical significance of differences between the mean values of the analyzed parameters in experimental groups was estimated by Duncan's multiple range test, using STATISTICA PL 9.0 software.

Results and discussion. The performance of growing-finishing pigs during two-stage and three-stage fattening is presented in Table 4. No significant differences between groups were found in the two-stage system. Over the entire fattening period, daily gains were at a similar level in pigs fed a control diet (group 1-C, 883 g) and diet 3 with a decreased protein content, supplemented with lysine, methionine, threonine and tryptophan (group 3, 882 g). A decrease in the total protein content of diets without exogenous amino acid supplementation reduced daily gains to 869 g (group 2). Feed intake per kg body weight gain was comparable in all groups, ranging from 2.94 kg to 2.97 kg. During the entire feeding trial, pigs fed diets with standard levels of protein and amino acids consumed the largest amounts of total protein per kg body weight gain. In group 1-C, the value reached 482 g and it was by 13.2% and 17.1% higher than in group 3 and group 2, respectively. Metabolizable energy intake oscillated around 39 MJ per kg body weight gain in all experimental groups.

Table 4. **Daily gains, feed conversion and carcass quality parameters in two-stage and three-stage production systems**

Specification	Two-stage production system			SEM	Three-stage production system			SEM
	Group				Group			
	1-C[1]	2	3		1-C[1]	2	3	
Daily gains, g								
30-110 kg	883	869	882	*12.708*	872^{a}	791^{b}	861^{a}	*14.412*
Relative,%	*100*	*98.4*	*99.9*		*100*	*90.7*	*98.7*	
Feed conversion, kg/kg								
30-110 kg	2.95	2.97	2.94	*0.053*	2.98^{a}	3.20^{b}	3.00^{ab}	*0.048*
Relative, %	*100*	*100.7*	*99.7*		*100*	*107.4*	*100.7*	
TP[2] intake, g/kg								
30-110 kg	482	413	418	*7.545*	461^{A}	424^{B}	405^{B}	*6.626*
Relative, %	*100*	*82.9*	*86.8*		*100*	*89.9*	*87.3*	
ME [3] intake, MJ/kg								
30-110 kg	38.64	38.91	39.25	*0.695*	38.63^{b}	41.82^{a}	39.88	*0.629*
Relative, %	*100*	*100.7*	*101.6*		*100*	*107.9*	*102.6*	
Carcass quality parameters								
Dressing percentage, %	82.8	82.1	82.9	*0.66*	82	79.6	82.5	*0.707*
Back fat thickness, mm	12.6	12.9	12.6	*0.504*	12.9	13	12	*0.334*
Carcass lean content, %	57.2	57	57.7	*0.401*	57.1	56.9	58.7	*0.502*

1-C[1] -control group; TP[2] -total protein; ME[3] -metabolizable energy; SEM – standard error of the mean; Mean values within a row with different letters differ significantly; small letters - $P \leq 0.05$, capital letters - $P \leq 0.01$

In the three-stage system, the performance parameters of pigs evaluated for the entire fattening period showed significant ($P \leq 0.05$) differences resulting from a decreased protein content of diets and amino acid supplementation (Table 4). In group 1-C, the average daily gains of pigs and feed intake per kg body weight gain reached 872 g and 2.98 kg, respectively. A low-protein diet (group 2) significantly decreased daily gains (by 9.3%, to 791 g) and increased feed consumption (by 6.9%, to 3.2 kg/kg). The addition of crystalline lysine, methionine, threonine and tryptophan to a low-protein diet (group 3) resulted in daily gains and feed conversion similar as in group 1-C fed a diet with standard levels of protein and amino acids, i.e. 861 g and 3 kg/kg, respectively. Pigs fed a diet with a decreased protein content (group 2) were characterized by highly significantly ($P \leq 0.01$) lower total protein intake per kg body weight gain (424 g), in comparison with control group animals (461 g). The addition of lysine, methionine, threonine and tryptophan to diets did not increase protein intake per kg body weight gain, which remained at a level of 405 g. Metabolizable energy intake per kg body weight gain was significantly ($P \leq 0.05$) higher in pigs fed a low-protein diet than in group 1-C (41.82 MJ ME/kg vs. 38.63 MJ ME/kg, a difference of 7.6%).

The results of previous research in this area are ambiguous. Kerr and Easter (1995) demonstrated that a 4% decrease in the total protein content of diets had no effect on the growth performance of pigs provided that the diets were supplemented with lysine, threonine and tryptophan. Similar findings were reported by Latimier and Dourmad (1993), Valaja et at., (1993), and Pfeiffer et al., (1995). In a study by Tuitoek et al., (1997 a, b) a 22% reduction in the total protein content of grower diets, relative to standard protein levels, had no negative effect on pig performance, but it deteriorated the performance of animals fed finisher diets. A decrease in daily gains and worse feed efficiency due to reduced dietary protein levels were also observed by Grela and Kowalczuk-Vasilev (2010), Figueroa et. al. (2002), and Reynolds and O'Doherty (2006).

In the two-stage system, carcass dressing percentage was similar in all groups, at 82.1% - 82.9%. In the three-stage system, it decreased in animals fed a low-protein diet (group 2, 79.6%), and in the remaining groups it ranged from 82% to 82.5%. In both systems, pigs receiving diets with protein content reduced by 15% were characterized by the thickest back fat (12.9 mm and 13.0 mm, respectively). In the three-stage system, the addition of exogenous amino acids to diets contributed to a decrease in back fat thickness, from 12.9 mm in group 1-C to 12.0 mm in group 3. The above results are consistent with the findings of Kay and Lee (1996) who reported that a reduction in dietary protein levels increases back fat thickness in growing-finishing pigs. A similar trend was also noted by Carpenter et. al. (2004). According to Van Lunen and Cole (2001), the above is due to the utilization of greater amounts of energy for lipid synthesis. In pigs fed high-protein diets, excess protein has to be converted to fat. In the present study, all pigs had a high carcass lean content, at 57% - 58%. The differences between groups were statistically non-significant. In both production systems, animals fed a diet with a reduced total protein concentration, supplemented with limiting exogenous amino acids (group 3), tended to have a higher carcass lean meat proportion.

The chemical composition, physicochemical and sensory properties of *m. longissimus dorsi (LD)* are shown in Table 5.

Table 5. **Chemical composition, physicochemical and sensory properties of *m. longissimus dorsi***

Specification	Two-stage production system			*SEM*	Three-stage production system			*SEM*
	Group				Group			
	1-C[1]	2	3		1-C[1]	2	3	
Chemical composition, %								
Dry matter	25.15	25.25	25.05	*0.14*	25.55	25.6	25.39	*0.133*
Total protein	21.95	21.89	21.63	*0.109*	21.98[a]	21.47[b]	21.69	*0.103*
Crude ash	1.18	1.18	1.16	*0.009*	1.18	1.18	1.19	*0.006*
Intramuscular fat	1.86	1.71	1.88	*0.152*	1.88	2.26	2	*0.118*
Physicochemical properties								
pH_{45}	6.28	6.17	6.08	*0.048*	6.17	6.16	6.26	*0.041*
pH_{24}	5.59	5.51	5.67	*0.053*	5.5	5.63	5.51	*0.043*
Water-holding capacity, cm^2	6.9	6.8	7.12	*0.121*	7.07	7.16	6.56	*0.194*
Meat color								
L* - lightness	58.68	58.79	58.74	*0.352*	59.54	58.3	57.96	*0.488*
a – redness	4.79[A]	5.27[AB]	5.97[B]	*0.183*	5.42	5.75	5.94	*0.19*
b – yellowness	13.88	14.15	14.45	*0.14*	14.33	14.07	14.3	*0.119*
Shear force (N)	28	29.5	29.22	*1.367*	25.74	26.29	28.5	*1.585*
Sensory properties, points								
Aroma – intensity	3.7	3.5	3.2	*0.138*	3.3	3.9	3.6	*0.165*
Aroma – desirability	5.0	5.0	5.0	*0.0*	5.0	4.9	4.8	*0.06*
Tenderness	3.6	3.7	3.6	*0.109*	3.5	3.9	3.7	*0.128*
Juiciness	4.2	3.8	3.9	*0.084*	4.1	4.0	3.9	*0.10*
Taste – intensity	4.0	4.1	3.9	*0.049*	4.2	4.0	4.2	*0.086*
Taste – desirability	4.9	4.9	5.0	*0.039*	4.8	4.8	4.9	*0.072*

SEM – standard error of the mean; Mean values within a row with different letters differ significantly; small letters - $P \leq 0.05$, capital letters - $P \leq 0.01$

In the three-stage system, a reduction in dietary protein concentrations significantly ($P \leq 0.05$) decreased (by 2.3%) the total protein content of meat, compared with the control group. A non-significant increase in the intramuscular fat content of meat was also noted. The addition of exogenous amino acids to a low-protein diet (group 3) decreased intramuscular fat content and increased total protein concentration in pork.

An analysis of the physicochemical properties of *m. longissimus dorsi* revealed no significant differences with respect to the majority of parameters. In both production systems, pH measured 45 minutes post mortem and ultimate pH were within the normal limits for RFN (red, firm, normal) meat, cited by Borzuta and Pospiech (1999). In the two-stage system, group 3 pigs were marked by the darkest color of *m. longissimus dorsi*, with a high (5.97) contribution of redness a^* ($P \leq 0.01$). There was a negative correlation between lightness L^* and pH determined 45 minutes and 24 hours post mortem, i.e. higher lightness values were accompanied by lower pH levels. A correlation between the pH of meat and color lightness L^* was also observed by Owens et. al. (2000). Meat with a higher pH is generally darker in color due to a higher water content of cells and higher light absorption (Bojarska et. al., 2003).

The scores for the sensory attributes of meat were high, regardless of the concentrations of dietary protein and amino acids, and production system. The above agrees with the findings of Wood et. al. (1994) who demonstrated that the desired taste and tenderness of pork can be achieved at the intramuscular fat content of muscle tissue of 2% - 3%. In the present experiment, the intramuscular fat content of meat was below the recommended level in the majority of experimental groups, which could insignificantly decrease the sensory quality of pork.

Conclusions. The results of this study indicate that in two-stage and three-stage production systems, pigs fed diets with standard total protein levels can have daily gains above 850 g and feed intake per kg body weight gain below 3.0 kg. In the two-stage system, a 15 % reduction in the total protein content of complete diets had no significant adverse effect on pig performance and carcass quality traits. The efficacy of low-protein diets was lower in the three-stage system than in the two-stage system - the growth rate of pigs decreased by 9.3% and feed consumption increased by 7.4%. The addition of lysine, methionine, threonine and tryptophan to low-protein diets improved pig performance, in particular in the three-stage production system. Diet supplementation with exogenous amino acids had no significant beneficial influence on slaughter value and meat quality.

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