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Influence of digestible crude protein reduction and amino acids additive in growing pigs' diets on their performance and nitrogen balance

Wpływ obniżonego poziomu białka ogólnego strawnego i dodatku aminokwasów krystalicznych w żywieniu rosnących świń na efekty produkcyjne i bilans azotu

Summary. The aim of the study was to determine the influence of protein level and amino acids additive (lysine, methionine, threonine and tryptophan) in growing-finishing pigs feeding on their performance but also on nitrogen balance. The animals (160 fatteners) were divided into 4 groups, kept in pens, 10 animals each. Group I (control) were fed with standard mixtures with digestible crude protein and amino acids level balanced according to the German norms (DLG), whereas the animals of experimental groups (II, III and IV) had diets containing a lowered digestible crude protein level (by a 10, 20 or 30% in relation to DLG, respectively). All experimental diets contained the same quantity of essential amino acids as the control group diet. Feed intake (daily) and body weight (4 times, each 20 days of fattening period) were controlled. The N-balance tests were performed in the metabolic cages on 4 porkers from each group at 45–50 and 90–95 kg BW. A decreased content of protein digestible at the end of small intestine by a 10% in relation to the requirements for German swine feeding standards (DLG), while supplementing essential amino acids, resulted in the normal growth rate, just slightly lower than in control group. Further lowering of protein content brought decline in swine performance. The results of nitrogen balance show that restricting dietary protein content by a 10% in relation to the German norms (DLG), while supplementing essential amino acids, can result in a reduction of nitrogen emission to the environment.

Key words: pigs, protein pcv, essential amino acids, performance, nitrogen balance

INTRODUCTION

The goal of pigs feeding has always been maximum pig performance (high body weight gains, low feed conversion ratio), however nowadays the emphasis is put to achieve this aim with regard for minimum excretion of unused biogenic components into the environment. Among the nutrients present in manure, nitrogen (N) and phosphorus (P) emission causes the greatest concern in the situation of increasing swine population and intensity of production, frequently with no rational manure management practice. The output of different forms of nitrogen from the pig facility per stall is approximately 10.5 kg annually [Kirchgessner and Roth 1991]. Therefore, one of the top issues is to implement such a nutritional strategy so that feed nutrient efficiency could be significantly improved through phase-feeding [Grela and Semeniuk 2008], nitrogen reduction (protein) [Kirchgessner *et al.* 1994] as well as various dietary supplements inclusion [Grela 2008]. Lowering protein content and tailoring its amount to actual animal requirement dependent on productive stages or physiological state of animal constitute a large potential to increase nutrient utilization and decrease nutrient waste [von Essen 1989]. The key factor is to maintain accurate amino acid balance in a well – formulated diet comprising appropriate feed ingredients with supplementation of their shortage by crystalline amino acids. Importantly, a declined N level in diets for pigs, apart from lower environmental burden, may be associated with compromised animal growth rate, carcass slaughter value and increased feed conversion ratio.

The objective of the research was to determine the effect of a reduced level of crude protein digested in the small intestine (pcv) compared with the German standards [DLG 2006], taking into account crystalline amino acids (lysine, methionine, tryptophane and threonine) supplementation in fatteners' diet on their performance and nitrogen balance.

MATERIAL AND METHODS

The research included 160 growers, (PL × PLW) × Duroc crossbreeds of initial body weight 24.5 ± 0.7 kg assigned into 4 groups. The animals were kept in 4 pens, 10 pigs each. Group I control – the animals fed according to the DLG [2006] swine feeding standards. Group II, III, IV – the animals received dietary protein digested before the end of the small intestine (pcv) decreased by approximately 10, 20 and 30% with essential amino acid level (lysine, methionine, tryptophan and threonine) supplementation to the level of the control group. A diet was formulated with wheat and barley grain meals, soybean meal, soybean oil, mineral-vitamin additives, crystalline amino acids and Toyocerin (Bacillus toyoi) probiotics. The pigs were fed total mixed ration twice a day. Throughout the fattening period, each experimental group was supplied with seven total mixed rations of approx. 13.0 MJ metabolizable energy and a varied content of protein digested at the end of the small intestine (pcv). The fatteners from the control (I) and (II-IV) experimental groups received the same amount of feed, subject to body weight (Table 1).

All the growers in pens were individually ear-marked with plastic ear-rings. The zoohygienic conditions, i.e. temperature, relative humidity and cooling were identical for all the treatment groups. Water was available from automatic water supply device. The feeds were examined for the basic nutrient contents as well as lysine, methionine,

tryptophan and threonine according to the AOAC methods [AOAC 2000]. The animals were weighed at the experiment onset, then every 20 days. The records of feed refusals in each group were monitored. The nitrogen balance examinations were conducted on 4 fatteners, placed in the metabolism cages, from the group of around 45–50 and 90–95 kg body weight. Urine and feces were collected for 24-hours. Urinary and fecal nitrogen concentration was determined using Kjeldahl method according to AOAC [2000].

Feed energy value was calculated using regression equations proposed by Kirchgessner and Roth [1983]. A level of protein digested before the end of small intestine (pcv) and four amino acids was calculated according to the values presented in the DLG [2006].

The variance analysis (ANOVA) was applied to test the obtained data, while significance of differences between mean values of the analyzed traits was determined by t-Student test [SAS 1996].

RESULTS AND DISCUSSION

The complete mixtures used for each animal group contained 12.95–13.04 MJ metabolizable energy. Daily supply of crude protein and four supplemented essential amino acids (lysine, methionine, tryptophan, threonine) digested before the end of the small intestine in the control (Table 1) as well as in experimental groups was close to the methodological assumptions, with slight deviation ranging between 1.3–2.4%.

Table 1. Daily feed intake and nutritive value of pig basic mixtures
Tabela 1. Dzienne pobranie paszy i wartość pokarmowa 1 kg standardowych mieszanek dla tuczników

Item Wskaźnik	Body weight of fatteners, kg Masa ciała tuczników, kg								
	30	40	50	60	70	80	90	100	110
Feed intake, kg/d Pobranie paszy, kg/d	1.15	1.45	1.77	2.15	2.62	3.00	2.92	2.92	3.08
Metabolizable energy, MJ Energia metaboliczna, MJ	12.96	12.96	13.01	13.01	12.91	13.02	12.98	12.97	13.03
Digestibility of crude protein (pcv), g Białko ogólne strawne (pcv), g	120	120	110	110	105	100	95	85	80
Lysine pcv, g Lizyna pcv, g	8.2	8.2	7.3	7.3	7.1	6.7	6.3	5.6	5.3
Methionine + cystine Metionina + cystyna pcv, g	4.5	4.5	4.0	4.0	3.8	3.7	3.5	3.2	3.0
Tryptophan pcv, g Tryptofan pcv, g	1.4	1.4	1.3	1.3	1.2	1.2	1.1	1.0	0.9
Threonine pcv, g Treonina pcv, g	5.2	5.2	4.7	4.7	4.5	4.3	4.1	3.7	3.5

Table 2. Average daily gains of fatteners (g/day)
Tabela 2. Przyrosty masy ciała tuczników (g/dzień)

Days of fattening Dni tuczu	Feeding groups Grupy żywieniowe				SEM
	I – 100%	II – 90%	III – 80%	IV – 70%	
1–20	498[a]	465[ab]	428[b]	401[b]	16.8
21–40	601[a]	572[ab]	548[b]	529[b]	23.1
41–60	806[a]	773[ab]	756[b]	737[b]	25.6
61–80	1038[a]	1007[a]	973[ab]	942[b]	26.9
81–100	991[a]	976[a]	948[b]	889[c]	24.5
1–100	787[a]	759[ab]	731[b]	700[b]	25.1

a, b, c – values in the same rows with different letters differ significantly at $p \leq 0.05$
a, b, c – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

Table 3. Feed conversion ratio (FCR) during fattening period, (kg/kg)
Tabela 3. Wykorzystanie paszy w tuczu świń, (kg/kg)

Days of fattening Dni tuczu	Feeding groups Grupy żywieniowe				SEM
	I – 100%	II – 90%	III – 80%	IV – 70%	
1–20	2.41[b]	2.58[b]	2.80[ab]	2.99[a]	0.11
21–40	2.49[b]	2.62[b]	2.74[ab]	2.83[a]	0.14
41–60	2.61[b]	2.72[ab]	2.78[a]	2.85[a]	0.12
61–80	2.69[b]	2.78[b]	2.88[ab]	2.97[a]	0.13
81–100	3.13[c]	3.18[bc]	3.27[b]	3.49[a]	0.14
1–100	2.67[b]	2.78[b]	2.89[ab]	3.03[a]	0.13

a, b, c – values in the same rows with different letters differ significantly at $p \leq 0.05$
a, b, c – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

Daily gains in the control group (I) appeared some lower than the expected ones (Table 2), yet they were found within the limits obtained at production conditions. It is noteworthy that the DLG standards for pig fattening are very scarce, with regard to a protein content in pig diets as compared to the Polish swine feeding requirements [Normy... 1993]. However, literature data concerning the maximum dietary protein reduction rate are divergent indeed. Cromwell [1996] or Tuitoek *et al*. [1997] report that a 2–3% decrease of protein level in a growing pigs' diet with concurrent supplementation by limiting amino acids does not evoke any losses in the relevant performance parameters (ADG or FCR). Similarly, other authors [Hahn *et al*. 1995, Kerr *et al*. 1995, Figueroa *et al*. 2002] inform that protein reduction in feed ration at the appropriate level of essential amino acids does not compromise animal growth rate. Conversely, according to Hansen *et al*. [1993] and Gomez *et al*. [2002] low dietary protein contributes to deteriorated swine performance. The earlier studies of the present authors showed that 10% reduction of level of protein digested at the end of the small intestine as compared to the DLG norms [DLG 2006] with concurrent supplementation by amino acids digestible to the end of small intestine to the amount in the control group pigs' diet allowed to obtain

appropriate daily gains only slightly lower than in the control [Grela *et al*. 2009]. Markedly lower daily gains were obtained in group III and IV, whose dietary protein level was lowered by 20 or 30% as compared to the DLG standards [DLG 2006]. The differences obtained between the experimental groups and the control at each fattening season were confirmed statistically.

Table 4. Nitrogen balance of pigs at 40–45 kg BW
Tabela 4. Bilans azotu u tuczników o masie 40–45 kg

Item Wskaźnik	Feeding groups Grupy żywieniowe				SEM
	I – 100%	II – 90%	III – 80%	IV – 70%	
Nitrogen intake, g/day Pobranie N, g/d	41.56^{a}	37.4^{b}	33.25^{c}	29.11^{d}	2.68
Faecal nitrogen excretion, g/day Wydalanie N w kale, g/d	6.86^{a}	5.95^{ab}	5.58^{b}	5.78^{b}	0.28
Urinary nitrogen excretion, g/day Wydalanie N w moczu, g/d	10.42^{a}	10.21^{b}	9.38^{c}	7.53^{c}	0.65
N retention, g/day Retencja N, g/d	24.28^{a}	21.24^{b}	18.29^{c}	15.80^{d}	1.83
N retention, % of N intake Retencja N, % N pobranego	58.42^{a}	56.79^{ab}	55.01^{ab}	54.28^{b}	0.93

a, b, c, d – values in the same rows with different letters differ significantly at $p \leq 0.05$
a, b, c, d – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

Table 5. Nitrogen balance of pigs at 90–95 kg BW
Tabela 5. Bilans azotu u tuczników o masie 90–95 kg

Item Wskaźnik	Feeding groups Grupy żywieniowe				SEM
	I – 100%	II – 90%	III – 80%	IV – 70%	
Nitrogen intake, g/day Pobranie N, g/d	54.25^{a}	48.62^{b}	43.65^{c}	37.71^{d}	3.53
Faecal nitrogen excretion, g/day Wydalanie N w kale, g/d	10.09^{a}	8.61^{ab}	8.38^{b}	6.57^{b}	0.72
Urinary nitrogen excretion, g/day Wydalanie N w moczu, g/d	12.76^{a}	11.35^{b}	10.65^{c}	6.77^{c}	1.28
N retention, g/day Retencja N, g/d	31.40^{a}	28.66^{a}	24.62^{b}	24.37^{b}	1.71
N retention, % of N intake Retencja N, % N pobranego	57.89^{b}	58.95^{b}	56.40^{b}	64.62^{a}	1.79

a, b, c, d – values in the same rows with different letters differ significantly at $p \leq 0.05$
a, b, c, d – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

Very high efficiency of feed utilization was observed in the control group as it reached 2.67 kg per 1 kg of body weight gain throughout the fattening period (Table 3). A decreased protein level in feed ration caused deteriorated feed efficiency. However, the poorest feed utilization efficiency was reported in a group of the most diminished dietary protein (group IV) and the differences as against the control group were statistically confirmed ($p \leq 0.05$). Similar findings at low protein diet in fattening period were reported by Figueroa *et al*. [2002] as well as Reynolds and O'Doherty [2006] at a lowered lysine content in a feed ration.

The results of balance examinations conducted on the growing pigs (Table 4 and 5) have shown considerable reduction of nitrogen losses in manure with concurrent similar coefficients of fecal digestibility of crude protein. Lowering a digestible protein content by 10% in accordance with the DLG standards [DLG 2006] in the diet of fatteners of 40–45 kg body weight resulted in decreased nitrogen retention by nearly 2% compared to its intake (Table 4). However, in the older fatteners (90–95 kg), no effect like that was recorded (Table 5). Interestingly, an almost 12% increase of nitrogen retention was noted in group IV fatteners of 90–95 kg body weight, with unfortunately, the worst performance parameters obtained. The studies by DeCamp *et al*. [2001] and Bridges *et al*. [1995] revealed that diminished dietary nitrogen concentration caused decreased urinary nitrogen output and increased retention as against the N input, that has been confirmed in the present investigations. The achieved results indicate that accurate estimate of the nutrient requirements and accuracy of compositional information [DLG 2006] do not allow for further manipulation in diet formulation aiming at dietary protein reduction. Although lowering digestible protein in diet may be an effective tool for reducing its output, it causes concurrent decreased daily gains and higher feed conversion ratio.

Recently, the extensive literature has addressed an issue of swine performance and nitrogen balance in fattening of pigs fed low protein diets with/without essential amino acids additive. The research findings of many authors [Bridges *et al*. 1995, DeCamp *et al.* 2001, Figueroa *et al.* 2002] point to the potential held for nitrogen output reduction with no any substantial losses of productivity. That however, referred only to crude protein decrease in a feed ration in compliance to the standards or recommendations about excessive protein in situation when it should meet animal actual requirement pattern or improper balance of essential amino acids. Using the modern swine feeding German standards DLG [Grela 2007, 2008] based on protein and amino acids digested before the end of small intestine (pcv) facilitates very accurate balancing of these feed ingredients and does not allow for further substantial (over 10%) protein decrease in pigs' diets.

CONCLUSION

The obtained performance parameters and nitrogen balance indices have revealed the potential, which is available to assist with lowering nitrogen excretion to environment through diminishment of dietary crude protein digested before the end of the small intestine (pcv) by 10% as against the DLG [2006] recommendations with supplement of digestible essential amino acids: lysine, methionine, threonine and tryptophane. However, a further effect of continued crude protein reducing (over 10%) proves to be markedly limiting pigs performance.

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Streszczenie. Celem podjętych badań było określenie wpływu obniżonego poziomu białka ogólnego strawnego (pcv) i dodatku aminokwasów krystalicznych (lizyny, metioniny, treoniny i tryptofanu) w żywieniu tuczników na ich efekty produkcyjne oraz bilans azotu. Zwierzęta (160 sztuk), podzielone na 4 grupy, utrzymywane były w kojcach po 10 sztuk w każdym. Grupa I (kontrola) otrzymywała standardowe mieszanki pełnoporcjowe o zalecanym poziomie białka ogólnego i aminokwasów trawionych do końca jelita cienkiego, zgodnie z niemieckimi normami DLG, zwierzęta zaś z grupy II, III i IV otrzymywały mieszanki o obniżonym o 10, 20 i 30% poziomie białka ogólnego w stosunku do zaleceń DLG. Aminokwasy – lizynę, metioninę, treoninę i tryptofan – w grupach doświadczalnych uzupełniano do poziomu w grupie kontrolnej. Zwierzęta były ważone czterokrotnie (co 20 dni trwania tuczu), przy systematycznej kontroli pobrania paszy. Badania bilansowe wykonano w klatkach metabolicznych na 4 wieprzkach z grupy przy masie ciała 40–45 i 90–95 kg. Ograniczenie poziomu białka trawionego do końca jelita cienkiego o około 10% w stosunku do zaleceń DLG, przy jednoczesnym uzupełnieniu aminokwasów strawnych do końca jelita cienkiego do ilości w paszy dla grupy I, pozwoliło uzyskać poprawne przyrosty dzienne, nieznacznie mniejsze niż w grupie kontrolnej. Dalsze ograniczanie poziomu białka przyczyniło się do pogorszenia efektów produkcyjnych tuczu świń. Uzyskane wskaźniki bilansu azotu wskazują na możliwość ograniczenia wydalania składników azotowych do środowiska poprzez zmniejszenie poziomu białka ogólnego strawnego (pcv) w paszy o 10% w stosunku do norm DLG, przy jednoczesnym dodatku aminokwasów egzogennych, lizyny, metioniny, treoniny i tryptofanu, według zaleceń DLG.

Słowa kluczowe: świnie, białko pcv, aminokwasy krystaliczne, efekty produkcyjne, bilans azotu