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The effect of dietary amino acid composition on protein and energy balance in growing pigs*

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ABSTRACT

Protein and energy deposition in the body were measured in 20 pigs from 25 to 70 kg body weight, which were fed isoprotein and isoenergetic diets adequate (A) in ileal digestible amino acid content, deficient in lysine by 20% (D) or 40% (VD), or containing lysine and methionine in 20% excess (E). Protein deposition in VD and D pigs was respectively 26 and 9% lower, whereas in the E pigs it was similar to that in A pigs. Utilization of digestible lysine was inversely (r=-0.52) related to the amount of protein deposited in the body. Dietary supplementation with amino acids had no effect on utilization of metabolizable energy (on average 33%). However, heat production related to maintenance and protein deposition was reduced by 0.38 kJ/kg$^{0.75}$ (P=0.07) per kJ energy additionally retained as protein.

KEY WORDS: growing pigs, ileal digestible amino acids, protein balance, energy balance

INTRODUCTION

Protein gain in the body is the outcome of the competing processes of protein synthesis and protein degradation (turnover). These processes change in similar or opposite directions depending on animal and dietary factors (Simon, 1989). Theoretically, any changes in the rate of protein turnover affect energy metabolism because both protein synthesis and protein degradation are energy-consuming processes (Reeds and Mersmann, 1991).

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It has been shown that turnover of protein in pigs changed when they were fed diets imbalanced by supplementation with amino acids (Salter et al., 1990; Saggau et al., 2000). However, short-term experiments on energy metabolism with pigs fed semi-synthetic diets varied in the biological value of protein (Fuller et al., 1987; Beyer et al., 2000) showed no significant relationship between protein and energy metabolism.

The aim of this work was to study the long-term influence of dietary amino acid composition when feeds were based on ingredients commonly used in pig nutrition. Diets were formulated according to ileal digestibility (apparent) of amino acids.

MATERIAL AND METHODS

Growing pigs of a synthetic line randomly allotted into four treatment groups (4 gilts from each of 5 litters) and from 25 to 70 kg body weight (BW) were fed a basal diet (group VD) or a basal diet partially or adequately supplemented with synthetic amino acids (groups D, A and E). The basal diet was composed of (g/kg): wheat, 696; rapeseed oilmeal, 220; maize starch, 60; and vitamin-mineral premix, 24. In 1 kg DM it contained about, g: crude protein, 193; ether extract, 17; ash 49, and gross energy, 18.8 MJ. The content and proportion of individual AA in the basal diet (diet VD; Table 1) were determined in a preliminary ileal experiment with surgically modified pigs (Buraczewska et al., 1999), but they were still below current recommendations (CVB, 1995). Diet D was supplemented with 0.21% L-lysine HCl, but it was still deficient in comparison with AA pattern (Table 1). Diet A (adequate) was supplemented with 0.42% L-lysine HCl and 0.018% L-threonine and 0.015% L-tryptophan according to the AA standard. Diet E was

TABLE 1

Content of ileal digestible lysine, methionine, treonine and tryptophan in diets for pigs

Amino acid	Diets with amino acids contents, %			
	VD very deficient	D deficient	A adequate	E In excess
Lysine	0.44	0.60 (0.16)	0.75 (0.31)	0.91 (0.47)
Methionine	0.24	0.24	0.24	0.29 (0.05)
Treonine	0.41	0.41	0.43 (0.018)	0.41
Tryptophan	0.12	0.12	0.14 (0.015)	0.12
Lys, g/MJ	0.35	0.47	0.59	0.71
Lys:Met:Thr:Trp	100:55:95:28	100:40:69:20	100:32:57:18*	100:32:45:13

in brackets is shown amount of amino acid of crystalic origin

* standard (CVB, 1995)

supplemented with 0.63% L-lysine HCl and 0.053% DL-methionine to maintain the mutual proportion of AA (100:32), but the concentration of these AA was in excess of requirements. The pigs were fed twice daily according to a scale adjusted to their metabolic body weight (120g/kg$^{0.75}$). They were kept in 2.6 m^2 separate pens in a thermoneutral environment.

The pigs were slaughtered at 70 kg body weight after 16-h fasting and then their carcass, hair and offal were analyzed for chemical composition. Additionally, 5 pigs were slaughtered at 25 kg body weight to provide information on initial body composition. The composition of feed, faeces, and body was analyzed according to AOAC procedures (1994). Gross energy in feeds was determined by bomb calorimetry. Digestibility of energy (faecal) was determined during a three-day collection in all pigs in the middle of the study at approximately 45 kg body weight. Metabolizable energy (ME) was estimated as DE x 0.965. Energy content in the body was estimated from the protein and fat content using the factors 23.86 and 39.76 kJ/g, respectively. Corrected heat production (HP') was calculated as ME - (1.4 fat gain+1.15 protein gain), where 1.4 is the equivalent of ME needed for fat deposition in growing gilts (Fandrejewski, 1992) and 1.15 is the equivalent of protein synthesis *in vitro* (Reeds and Mersmann, 1991).

Statistical analyses were performed using SAS procedures (1997). In analysis of variance two factors, dietary treatments and litter, were taken into account. Differences between groups were tested at $P<0.05$.

RESULTS

Average daily gains and feed conversion rate increased as the diets' lysine content rose from 4.4 (group VD) to 7.5 g/kg (group A; Table 2). Further increasing lysine to 9.1 g/kg (group E) did not change growth performance parameters.

Pigs from Lys-deficient groups deposited daily 37 (VD) or 26% (D) less protein than the remaining pigs (Table 3). Groups A and E did not differ in respect to

TABLE 2

Growth performance of pigs fed from 25 to 70 kg diets of adequate (A) in ileal digestible amino acids content or deficit in lysine by 20% (D) or 40% (VD) or containing lysine and methionine in 20% excess (E)

	VD	D	A	E	SEM
Feed intake, kg/day	2.11	2.11	2.11	2.09	0.07
Daily gain, g	673^a	778^b	808^b	808^b	7.07
Feed conversion ratio	3.14^a	2.71^b	2.61^b	2.58^b	0.03

^{a,b} – $P<0.05$

TABLE 3

Protein balance (g per $kg^{0.75}$) of pigs given diets of adequate (A) in ileal digestible amino acids content or deficit in lysine by 20% (D) or 40% (VD) or containing lysine and methionine in 20% excess (E)

	VD	D	A	E	SEM
Lysine (ileal digestible) intake	0.51[a]	0.70[b]	0.88[c]	1.06[d]	0.004
Protein deposition	5.48[a]	6.79[b]	7.44[b]	7.34[b]	0.110
Crude protein utilization [1]	0.28[a]	0.34[b]	0.38[b]	0.38[b]	0.006
Lysine utilization [1]	0.78[a]	0.71[ab]	0.62[b]	0.51[c]	0.091

[1] assuming lysine content in the body gain as 7.3 g/16 gN (Wasilewko et al., 1996)
[a,b] – $P<0.05$

the amount of protein deposited in the body of pigs. Utilization of lysine linearly decreased as protein deposition increased ($r = -0.52$).

The energy balance (Table 4) showed that pigs from treatment VD deposited less energy in protein form than pigs fed diets supplemented with AA. Retention of energy as fat was highest ($P>0.05$) in the pigs fed the unsupplemented basal diet (VD). However, gross utilization of energy (RE/ME) was almost the same in all groups (32.4-33.4%).

The value of RE_{prot}/RE_{fat} depended more on the rate of protein deposition ($t=26.7$) than that of fat ($t=7.9$). The HP' was somewhat higher in pigs fed the basal diet (857 kJ/$kg^{0.75}$) than those fed diets supplemented with synthetic amino acids, which was a loss of 836-843 kJ energy/$kg^{0.75}$. However, HP', relating to the amount of energy deposited in protein, decreased ($P<0.01$) with increasing protein deposition in the body.

TABLE 4

Energy metabolism, kJ/$kg^{0.75}$ of pigs given diets of adequate (A) in ileal digestible amino acids content or deficit in lysine by 20% (D) or 40% (VD) or containing lysine and methionine in 20% excess (E)

	VD	D	A	E	SEM
Metabolizable energy	1499	1494	1484	1469	4.58
Retained energy as protein (RE_{prot})	131[a]	162[b]	176[b]	175[b]	2.83
Retained energy as fat* (RE_{fat})	354	337	315	312	5.85
RE_{prot}/RE_{fat}	2.71[a]	2.09[b]	1.81[b]	1.81[b]	0.06
Retained energy/metabolizable energy	0.324	0.334	0.331	0.331	3.08
Heat production	1014	995	993	982	7.00
Heat production corrected* (HP')	857	841	843	836	7.89
HP'/ RE_{prot}	6.54[a]	5.19[b]	4.79[b]	4.81[b]	0.103

* effect of dam ($P<0.05$)
[a,b] – $P<0.05$

DISCUSSION

The diets used in this study were based on wheat and rapeseed meal, which are lysine-deficient ingredients. Particularly the latter is an example of feedstuffs with imbalanced lysine to sulphur amino acids. Therefore, supplementation of a basal diet with AA increased the rate of protein deposition and confirmed that lysine is the first limiting AA in cereal-rapeseed meal diets. In contrast, additionally supplying Lys and Met without simultaneously supplementing indispensable AA did not further increase the protein deposition rate, which emphasizes the importance of the „ideal" protein principle in pig feeding.

In the present study, improving the biological value of protein in the diet resulted in increasing protein deposition and decreasing fat deposition. However, gross utilization of energy remained unchanged, which is in agreement with studies on pigs fed semi-synthetic diets (Fuller et al., 1987; Beyer et al., 2000). Nonetheless, the lack of differences in gross energy utilization is in opposition to the fact that the efficiency of energy utilization for protein retention is markedly lower than for fat retention (ARC, 1981), especially when energy retention is measured by the comparative slaughter technique (Fandrejewski, 1992). In growing animals, the energy costs of maintenance and of protein deposition should be considered jointly rather than separately (Kielanowski, 1976). This is because deposition of protein involves an overall increase of energy metabolism, which is probably partly due to an increase in protein turnover (Fuller et al., 1987). In the study of Fandrejewski (1992), increasing protein deposition through dietary rations increased HP' by 2.9 kJ per kJ of energy retained in protein form. In the present work, a regression coefficient of HP' on the rate of energy deposited in protein ER_{prot} (both in kJ per $kg^{0.75}$) was reduced by 0.38±0.11 $kJ/kJ^{0.75}$ (P=0.07) per kJ energy additionally retained as protein. This suggests that altering the quantity or quality of protein in pig nutrition changes energy metabolism related to protein anabolism in opposite directions, and at different rates.

CONCLUSIONS

Improving the amino acid composition of diets increased the protein deposition rate and protein/fat ratio in the body. It also reduced dissipation of energy as heat, however, the amount of energy saved in this way was not large. It seems that an excess of synthetic amino acids in diets for growing pigs does not significantly change their protein and energy metabolism.

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STRESZCZENIE

Wpływ składu aminokwasowego diety na bilans białka i energii u rosnących świń

Bilans białka i energii określono metodą ubojową na 20 rosnących świniach, od 25 do 70 kg, żywionych izobiałkową i izokaloryczną paszą zawierającą aminokwasy strawne (w jelicie cienkim) w ilości zgodnej z normami (A), lub obniżoną zawartością lizyny o 20 (D) i 40% (VD), bądź zawierającą lizynę i metioninę w 20% nadmiarze. Stwierdzono, że odłożenie białka u świń żywionych paszą niedoborową pod względem lizyny było o 9-26% niższe niż w grupie kontrolnej. Wykorzystanie lizyny strawnej pogarszało się wraz ze zwiększaniem poziomu odkładanego białka w ciele (r=-0,52). Wykorzystanie pobranej energii metabolicznej na jej odłożenie w ciele wynosiło średnio 33% i nie zależało od czynnika doświadczalnego, natomiast straty energii w formie ciepła powstającego w wyniku potrzeb bytowych i odłożenia białka zmniejszały się o 0.38 kJ (P=0,07) wraz ze zwiększaniem się retencji energii w białku o 1 kJ/kg$^{0.75}$ Nadmiar lizyny i metioniny spowodowany dodatkiem aminokwasów syntetycznych nie zróżnicował wyników bilansu białka i energii.