Journal of Animal and Feed Sciences, 10, 2001, 633 – 647

The performance and body composition of growing pigs during protein or energy deficiency and subsequent realimentation

G. Skiba, H. Fandrejewski, St. Raj and D. Weremko

The Kielanowski Institute of Animal Physiology and Nutrition,
Polish Academy of Sciences
05-110 Jabłonna, Poland

(Received 10 April 2001; accepted 6 November 2001)

ABSTRACT

Seventy-eight 15 kg Polish Landrace gilts were allocated to three feeding regimens (C, E, P). Up to 25 kg the C pigs (control) were fed 95% of *ad libitum* intake; the group E pigs consumed 40% less energy, while group P animals received 40% less protein compared with group C. From 25 to 70 kg all of the pigs were fed diets differing in energy density (L - 12.4 MJ ME; H - 13.2 MJ ME) at restricted feeding (R) or *ad libitum* (A) levels. Animals were slaughtered at 25 kg (n=12) and 70 kg (n=66) and their bodies were analyzed for physical and chemical composition. From 15 to 25 kg the P and E pigs grew slower than controls (367, 242 vs 513 g/day). At 25 kg the P pigs had 185 g fat and 142 g protein per kilogram empty body, and entrail weight similar to C pigs. The E pigs had 90 g fat and 163 g protein per kilogram empty body and their entrails were 12% smaller compared with group C and P pigs. From 25 to 70 kg the average daily gain of pigs as well as their physical and chemical body composition at 70 kg did not depend on previous feeding. However, the rate of recovery of particular chemical body components depended on feeding intensity as well as on the previous feeding regimen. It was found that the compensatory response of pigs took about 2-3 weeks and previously underfed pigs are able to fully compensate their anatomical and chemical body composition.

KEY WORDS: pigs, compensatory growth, body composition

INTRODUCTION

Studies on the compensatory response of the pigs indicate that restricted feeding of pigs decreases their growth rate, however during the following period of growth when a diet adequate for animal requirements is used (realimentation) pigs can increase their growth rate and better utilize feeds (Kyriazakis et al., 1991; Stamataris et al., 1991).

Animals can be restricted in protein or energy intake. Both kinds of restriction change the anatomical and chemical body composition but the scale and quality of these changes depend on many factors, e.g., kind, severity and duration of the restriction feeding (Bikker, 1994; Fandrejewski, 1994; Quiniou et al., 1995).

Data concerning the chemical body composition of pigs during realimentation are scarce, but they suggest that the kind of previous restriction is the most important factor that influences chemical body composition during realimentation (Stamataris, 1991; de Greef, 1992).

In recent studies on compensatory responses, during realimentation pigs were usually fed one kind of diet, while the nutritional value of feed (Fandrejewski, 1994) as well as feeding intensity (Bikker, 1994) can influence the compensatory response. Thus, the results of work done so far cannot be compared directly. We have also not found any study simultaneously comparing the compensatory response of pigs to previous protein or energy underfeeding.

This study was conducted to test the hypothesis that the kind of underfeeding as well as feeding system and kind of diet used during realimentation influence the compensatory response in respect to chemical and anatomical body composition.

MATERIAL AND METHODS

Animals and experimental design

The experiment encompassed two periods of pig growth: *restriction* from 15 to 25 kg and *realimentation* from 25 to 70 kg. At 15 kg body weight, 78 piglets were randomly divided into three groups (C, E, P - Figure 1) and up to 25 kg the C pigs were fed at a feeding level corresponding to 95% of *ad libitum* intake while the E

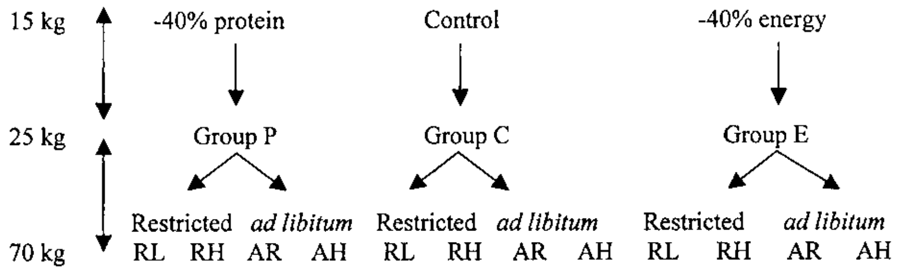

Figure 1. Design of the study

group consumed 40% less energy and the P group, 40% less protein compared with group C. The energy intake of the P pigs was comparable to the C pigs. From 25 to 70 kg all pigs were fed diets with a low (L) or high (H) energy content on a *restricted* feeding level (R, groups LR, HR) or *ad libitum* (A, groups LA, HA) (Figure 1). The aim of this procedure was to eliminate the influence of voluntary feed intake during realimentation on the compensatory response. Daily rations for the R pigs were changed weekly according to their body weight but feed consumed by pigs fed *ad libitum* was replenished twice a week. During both restriction and realimentation the pigs were kept in individual pens.

Diets

The composition and nutritional value of the diets are presented in Table 1. From 15 to 25 kg body weight the C and E pigs consumed a basal diet containing 12.9 MJ ME and 167 g CP per kg. The diet for the P pigs (13.1 MJ ME, 130 g CP) was composed by diluting the basal diet with maize starch (2:1). The diets fed to animals during realimentation were based on rapeseed oilmeal (L, 12.4 MJ ME, 166 g CP) or on soyabean meal as the main source of protein (H, 13.2 MJ ME,

TABLE 1

Composition and nutritional value of the diets

	Realimentation (25-70 kg)			
	Group		Group	
	C and E	P	L	H
	Nutritional value			
Metabolizable energy, MJ/kg diet	12.9	13.1	12.4	13.2
Crude protein, g/kg diet	167	130	166	176
Methionine+cysthine:lysine ratio	0.59	0.58	0.61	0.60
Lysine/ME ratio, g/MJ	0.76	0.56	0.88	0.70
	Diet composition, g/kg DM			
Rapeseed oilmeal	-	Obtained by	250	Composition
Protein concentrate	200	dilution	-	of the diet
Wheat	496	a basal diet	523	reserved
Barley	290	with maize	200	by producer[1]
Mikromiks	10	starch in	14	
Lysine HCl	-	proportion	4.2	
Dicalcium phosfatate	4	2:1	1.5	
NaCl	-		1.5	
Limestone flour	-		5.8	

[1] Central Soya Company

176 g CP). Those diets differed in the lysine:energy ratio resulting from the high lysine supplementation to the L diet to cover the optimal proportion between sulphuric amino acids and lysine.

Slaughter procedure and body analysis

Twelve pigs were slaughtered at 25 kg (four from each group) and 66 at 70 kg. After slaughter the hair was removed from the body, then the entrails including the gastrointestinal tract were emptied and weighed. Carcass, entrails and hair were analyzed for protein, fat, ash and water content (AOAC, 1994). For calculation purposes, the chemical composition and weight of the hair were included in the carcass.

Statistical analysis

Statistical analyses were performed by three-way analysis of variance ANOVA using the Statgraphics version 6.0 Plus software.

RESULTS

Restriction phase (15-25 kg)

The average daily gain of the E and P pigs was reduced ($P<0.01$) as compared with group C (242, 367 vs 513 g, respectively). The feed conversion ratio was increased by 34.8 % in group P and by 30.0 % in E as compared with group C. At 25 kg, the P and E pigs were older ($P<0.01$) than the C pigs by 7 and 20 days, respectively (Table 2).

The weight of entrails of the C and P pigs was similar (5.0 and 5.1 kg) and higher ($P<0.01$) compared with the E group (4.4 kg). However, the weight of the gastrointestinal tract of the E pigs was the smallest ($P<0.01$) (1.90 kg) as compared with groups C (2.47 kg) and P (2.39 kg) (Table 2). At 25 kg the protein content in the body of the P pigs was lower (142 g/kg) and the E pigs higher (163 g/kg) as compared with the C pigs (152 g/kg) (Table 2). The kind of restriction influenced ($P<0.01$) the total fat content in the body (129, 185 and 90 g/kg, respectively for the C, P and E pigs). The fat:protein ratio in the body of pigs differed ($P<0.01$) between groups (0.85, 0.55, 1.30, respectively in the C, E, and P pigs).

Experimental treatment did not affect the lean body mass composition of pigs (Table 2) with the exception of the ash:protein ratio. This value differed significantly only between groups E (0.199) and P (0.229).

TABLE 2

The performance of pigs from 15 to 25 kg and body composition of the pigs at 25 kg

	Groups			
	C	P	E	s.e.
		Performance		
Average daily gain, g	513^{C}	367^{B}	242^{A}	5.50
Feed conversion ratio, MJ ME/kg gain	26.7^{A}	36.0^{B}	34.7^{B}	1.11
Age at 25 kg, days	74^{A}	81^{B}	94^{C}	0.7
		Body composition		
Empty body weight, kg	23.15	23.36	22.56	0.24
Carcass weight, kg	18.15	18.26	18.16	0.20
Entrails weight, kg:	5.00^{B}	5.10^{B}	4.40^{A}	0.08
gastrointestinal tract[1], kg:	2.47^{B}	2.39^{B}	1.97^{A}	0.34
liver, g	623^{B}	612^{B}	411^{A}	13.3
small intestines, g	907^{B}	868^{B}	711^{A}	27.4
large intestines, g	496^{B}	500^{B}	394^{A}	9.0
		Chemical body composition, g/kg empty body weight		
Protein	152^{B}	142^{A}	163^{C}	1.71
Fat	129^{B}	185^{C}	90^{A}	1.56
Water	683^{B}	647^{A}	717^{C}	4.00
Ash	33.1	32.4	32.5	0.54
Fat/protein	0.85^{B}	1.30^{C}	0.55^{A}	0.01
Water:protein ratio	4.86	4.56	4.40	0.07
Ash:protein ratio	0.217^{ab}	0.229^{b}	0.199^{a}	0.004

^{ABC} P<0.01

^{abc} P<0.05

[1] stomach + small intestines + large intestines + liver + pancreas + spleen

Realimentation (25-70 kg)

The feed intake of pigs fed *ad libitum* did not differ significantly between pigs fed the low (L) and the high (H) energy diet (2.39 vs 2.48 kg/day). However, the pigs fed the H diet consumed more (P<0.01) energy (30.36 vs 28.16 MJ ME/day) and grew faster (P<0.01) (938 vs 846 g/day) but had a similar feed conversion ratio (FCR) (32.6 vs 33.5 MJ ME/kg body gain) compared with the pigs fed the L diet (Table 3). The pigs having free access to feed (A) as compared with those fed according to a *restricted* feeding system (R) consumed more (P<0.01) energy (31.2 vs 27.3 MJ ME/day) and grew faster (P<0.01) (961 vs 823 g/day) but their FCR was insignificantly lower (32.7 vs 33.5 MJ ME/kg gain).

TABLE 3

Performance of pigs during realimentation and the body physical and chemical composition

	Restricted Feeding (R)						*Ad libitum* feeding (A)						s.e.	Influence of			Interaction
	low energy diet (L)			high energy diet (H)			low energy diet (L)			high energy diet (H)							
	C n=6	P n=6	E n=7	C n=5	P n=5	E n=5	C n=6	P n=5	E n=5	C n=6	P n=4	E n=6		fee-ding	diet	group	
Performance 25-70 kg																	
Feed intake, kg/day	2.16	2.13	2.13	2.10	2.14	2.15	2.31	2.33	2.53	2.48	2.49	2.48	0.03	ns	ns	Ns	
ME intake, MJ/day	26.8	26.5	26.4	27.6	28.2	28.4	28.8	29.1	31.4	32.6	32.8	32.6	0.22	**	**	Ns	
Average daily gain, g	732	778	818	848	907	855	878	899	971	1039	1026	950	11.0	**	**	Ns	
Feed conversion ratio, MJ ME/kg body gain	36.7	34.3	32.3	32.7	31.6	33.4	32.9	32.5	32.3	31.6	32.0	34.7	0.34	ns	ns	Ns	
Performance 15-70 kg																	
Average daily gain, g	677	650	571	770	717	600	743	691	601	886	778	637	9.85	**	**	**	
Feed conversion ratio, MJ ME/kg gain	34.9	34.6	32.8	31.3	32.2	33.4	32.5	34.0	33.9	30.4	32.5	34.4	0.37	ns	*	Ns	
Age, day	136	140	149	127	130	146	125	131	142	117	123	143	0.72	**	**	**	
Body composition																	
Liveweight, kg	70.2	70.8	69.7	69.8	68.9	69.1	69.8	69.9	71.0	69.8	67.6	70.1	0.22	ns	ns	Ns	
Empty body weight, kg	66.1	67.0	65.0	66.0	65.6	64.8	64.9	64.5	65.6	65.1	63.4	65.8	0.18	**	ns	Ns	
Carcass weight, kg	54.0	55.1	53.3	53.5	53.3	52.1	52.2	51.5	52.1	52.2	50.3	53.0	0.12	**	*	Ns	
Entrails weight, kg	12.1	11.8	11.7	12.5	12.3	12.7	12.7	13.0	13.5	12.9	13.1	12.8	0.01	**	ns	Ns	
Gastrointestinal tract, kg:	5.00	4.73	4.71	4.59	4.61	4.71	4.90	5.14	5.38	4.86	4.81	4.83	0.05	**	**	Ns	
liver, g	1545	1501	1464	1261	1268	1285	1662	1754	1880	1392	1363	1380	15.0	**	**	Ns	AB*
small intestines, g	1415	1334	1323	1350	1410	1355	1399	1438	1472	1571	1578	1464	20.0	**	ns	Ns	
large intestines, g	1264	1120	1152	1230	1165	1282	1105	1202	1268	1196	1245	1266	18.0	ns	ns	Ns	
Chemical body composition, g/kg empty body weight																	
Protein	157	160	163	155	157	160	153	151	153	159	153	156	0.75	**	ns	Ns	
Fat	196	188	175	184	188	165	199	207	179	169	190	179	2.70	ns	**	Ns	
Water	618	623	632	635	627	652	620	613	636	641	626	634	2.50	ns	**	Ns	
Ash	28.1	28.8	29.1	25.6	27.1	22.3	28.2	28.3	31.6	30.4	30.7	30.6	0.30	ns	**	Ns	
Fat:protein ratio	1.25	1.18	1.07	1.19	1.20	1.03	1.30	1.37	1.17	1.06	1.24	1.15	0.02	*	**	Ns	BC*
Water:protein ratio	3.94	3.89	3.88	4.10	3.99	4.08	4.05	4.06	4.16	4.03	4.09	4.06	0.02	ns	*	Ns	
Ash:protein ratio	0.179	0.180	0.179	0.165	0.173	0.140	0.184	0.187	0.207	0.191	0.201	0.196	0.02	ns	**	Ns	

** $P<0.01$, * $P<0.05$; ns - difference nonsignificant; experimental factors: A- feeding system; B- diet; C- group

The energy intake was only slightly higher in both previously underfed groups of pigs (P and E) compared with the C pigs (29.1 and 29.7 vs 29.0 MJ ME/day, respectively) (Table 3). As a consequence, their growth rate did not significantly differ from the C pigs (903 and 899 vs 874 g/day, respectively).

The growth rate from 15 to 70 kg was the lowest in the E (602 g/day) and the highest in the C pigs (709 g/day) while the P pigs grew 709 g/day (Table 3). As a result, at the end of the study both previously underfed groups of pigs were still older, by 5 (group P) and 19 days (group E) compared with the C animals. However, when the age difference at 70 kg is compared with that at 25 kg, it is seen that the P and E pigs made up for time lost during restriction by 2 and 1 days, respectively.

The pigs having free access to feed (A) were at 70 kg younger by 8 days (P<0.01) and their entrails were 0.8 kg heavier (P<0.01) compared with the pigs fed at the restricted level (R) (Table 3).

The total gastrointestinal tract of the group A pigs was heavier (P<0.01) (4.99 vs 4.73 kg), as well as the liver (1572 vs 1387 g) and small intestines (1487 vs 1365 g) compared with the R pigs. An interaction (P<0.05) of feeding level x kind of diet in liver weight was found. A difference in liver mass between the R and A pigs fed the high energy diet (H) amounted over to 8 % (1271 vs 1387 g) while this difference between R and A pigs fed the low energy diet (L) diet was almost twice as high (15 %; 1501 vs 1765). The gastrointestinal tract of the H pigs was heavier (5.40 vs 4.98 kg) but the liver was over 19 % lighter as compared with the L pigs (1325 vs 1634 g).

The R pigs as compared with the A pigs had a greater (P<0.01) protein (159 vs 154 g/kg) but only slightly lower (nonsignificant difference) fat content (183 vs 187 g/kg) and better (P<0.05) fat:protein ratio (1.16 vs 1.25) but lower (P<0.05) water:protein ratio (3.98 vs 4.08) in their bodies (Table 3).

In comparison with the pigs that consumed the L diet, the H pigs had less (P<0.01) fat (179 vs 191 g/kg) and improved (P<0.01) fat:protein ratio (1.15 vs 1.25) but a lower ash:protein ratio (P<0.01) (0.178 vs 0.186) in the empty body.

The previous feeding regimen did not influence the body composition of pigs at 70 kg (Table 3). However, the protein content in the body of the E pigs was still slightly higher (158 g/kg) and in the P pigs similar (155 g/kg) compared with the C pigs (156 g/kg). The P pigs were still slightly fatter (193 g/kg) and those from group E, slightly thinner (181 g/kg) compared with the group C pigs (187 g/kg). The fat:protein ratio in the body did not differ between groups. However, its value in the E pigs was still insignificantly improved, whereas in the P pigs, insignificantly worse compared with those in group C (1.15 and 1.25 vs 1.20). An interaction (P<0.05) of feeding system x group in fat:protein ratio was detected. A change from *restriction* to *ad libitum* feeding did not increase the fat:protein ratio in the C pigs (1.22 vs 1.18) but this value increased considerably in group P (from 1.19 to 1.30) and E pigs (from 1 .05 to 1.16).

DISCUSSION

The results of our study indicate that low energy consumption decreased the rate of daily gain of pigs more than protein restriction.

The feeding system employed from 15 to 25 kg affected the weight of entrails of pigs but only in those that consumed an insufficient amount of energy. The weight of the liver, small and large intestines as metabolically very active organs was reduced the most by decreasing the energy supply and their growth was inhibited before that of muscle tissue, a conclusion also arrived at earlier by Yahya and Millward (1994). In our study, the weight of the liver was only 66%, small intestines 78% and large intestines 79% of the mass of these organs in pigs that consumed a sufficient amount of energy. Data from literature indicate that a lower mass of metabolically active organs decreases the maintenance requirements of animals (e.g., Kong et al., 1985) which could influence their compensatory response during realimentation.

Our results concerning the lower weight of the total gastrointestinal tract of the pigs on a low energy diet are in good agreement with data from literature (e.g., Stamataris et al., 1991; Bikker, 1994). The lack of differences in the weight of the entrails as well as the liver, small and large intestines between control pigs and those consuming lower daily amounts of protein confirmed that growth of this part of the body is rather insensitive to reduction of protein intake if the energy intake is not limited. These results also suggest that the supply of energy is an important factor influencing the growth of internal organs. It was also found that the feeding regimen during restriction strongly influences the chemical body composition of pigs at the end of this phase. A lower protein and higher fat content in the body of pigs consuming low amounts of protein was caused by an excess of energy over requirements as well as the possibility for accruing protein. Inversely, too low an energy supply increases the activity of lipolytic enzymes, especially in the backfat to cover the energy requirements of animals (Whang et al., 2000) and as a consequence the fat content in the body declines. On the other hand, during energy deficiency the body protects amino acids against using them as an energy source (Simmon, 1989) and does not decrease the protein content in the body.

The results of our study indicate that during realimentation, the growth rate of pigs previously consuming a low amount of protein as well as those fed a low amount of energy did not differ significantly compared with controls. Thus, if compensatory growth is considered as a higher growth rate of previously underfed animals, these pigs did not show any compensatory growth. A consequence of this was the older age of both previously underfed groups at the end of the study. That fact indicates that the possibility of fully recovering weight-for-age is rather unlikely. However, if the growth of pigs during the following weeks of realimentation is considered it was clear that both previously underfed groups of pigs showed compensatory growth, except those fed *ad libitum* on high energy diet (Figures 2 and 3). The longer realimentation lasted, the smaller the difference between both previously underfed groups of animals was found. These findings confirm a theory (Ryan, 1989) that compensatory growth occurs for only a very limited time

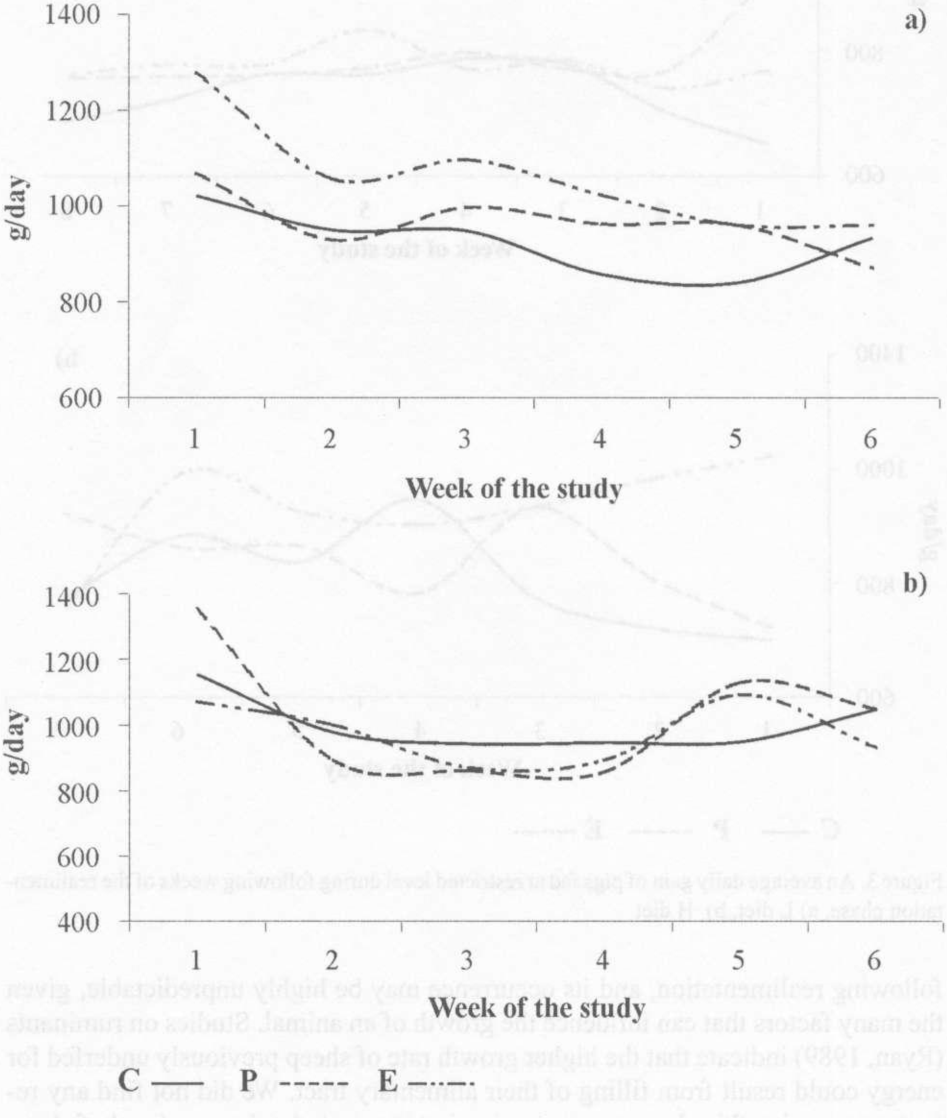

Figure 2. An average daily gain of pigs fed *ad libitum* during following weeks of the realimentation phase, a) L diet, b) H diet

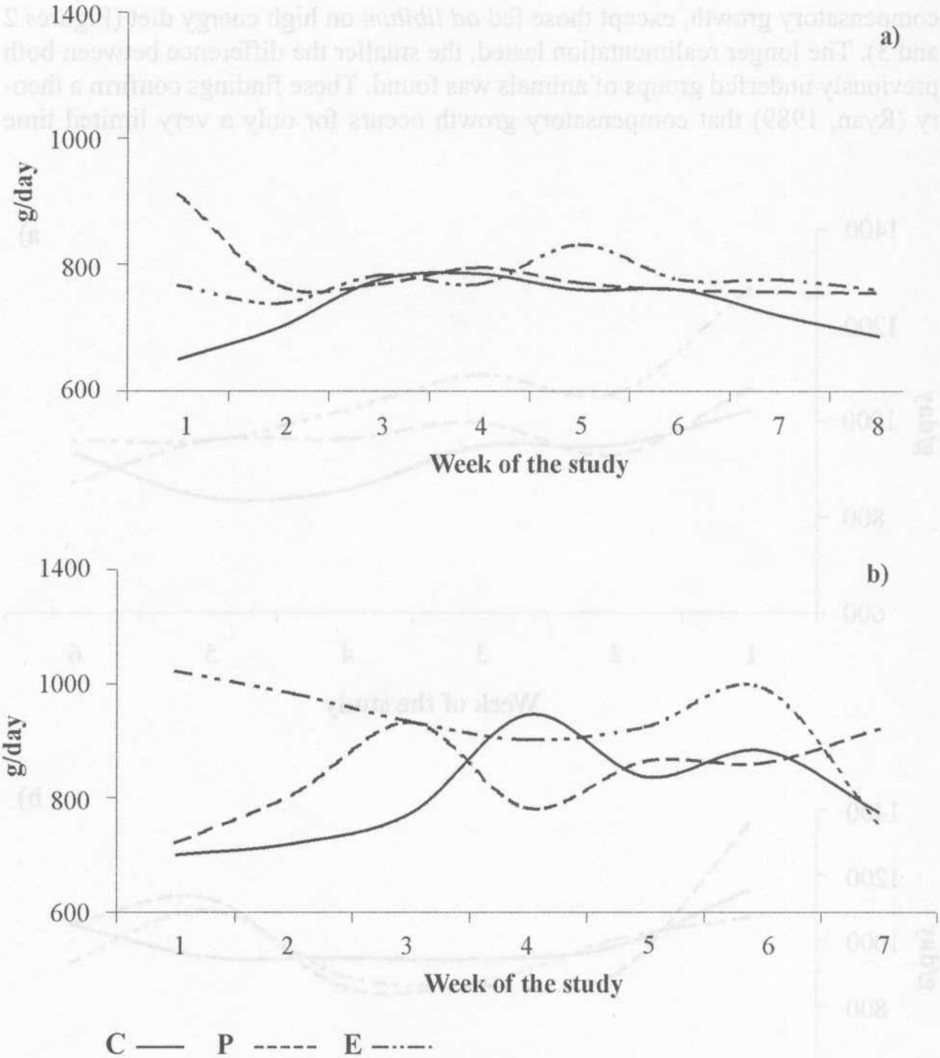

Figure 3. An average daily gain of pigs fed at restricted level during following weeks of the realimentation phase, a) L diet, b) H diet

following realimentation, and its occurrence may be highly unpredictable, given the many factors that can influence the growth of an animal. Studies on ruminants (Ryan, 1989) indicate that the higher growth rate of sheep previously underfed for energy could result from filling of their alimentary tract. We did not find any reports concerning this phenomenon in pigs, but in our study pigs previously fed at a low energy level showed compensatory growth at both *restricted* and *ad libitum* feeding (Figures 2 and 3). This could mean that *ad libitum* feeding during realimentation does not determine the compensatory response. It also seems that the lower mass of metabolically active organs (such as the liver, small and large intestines) of the pigs on an energy-restricted diet caused lower maintenance requirements of these pigs (Koong et al., 1985) and during following realimentation more energy from the diet could probably be allocated to covering growth requirements. In the case of pigs previously consuming inadequate amounts of protein, an increased a fat content in their body could play an important role (de Greef et al., 1992).

The final protein and fat content in the body did not differ between groups. From this point of view, previously underfed animals recovered their chemical body composition, a result which has been shown in only a very few studies (e.g., Sarkar, 1983; Fandrejewski, 1994).

The results of our study indicate that the feeding level (independent of the kind of diet) and kind of previous underfeeding as well as recovering components of the body influence the rate of recovery. At a restricted feeding level, pigs previously fed a low protein diet were able to recover their protein content in the body before they reached the target weight because at 70 kg their body contained more protein than the control animals (Figure 4). This was due to the large fat stores deposited in their body during restriction that in the subsequent realimentation could be mobilized as an extra source of energy for protein deposition, which was already indicated in an earlier study (e.g., Close et al., 1978). At this feeding level, the fat content in the body of our pigs resembled that of control pigs. However, at *ad libitum* feeding the amount of energy that animals could use (consumed with feed

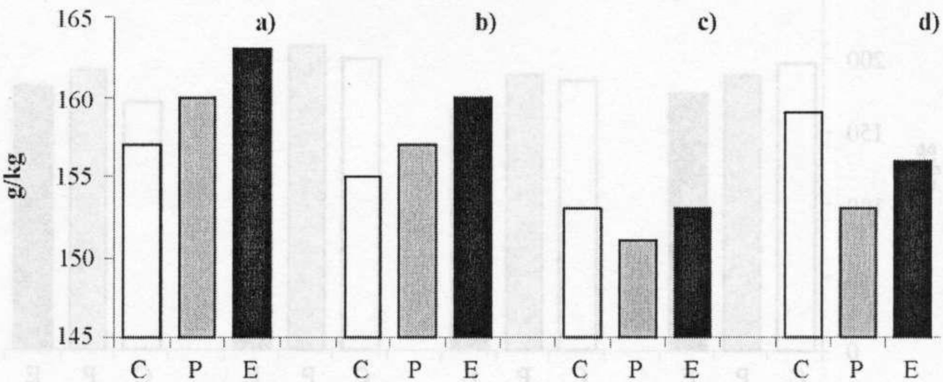

Figure 4. A protein content in the body of pigs at 70 kg body weight in respect to feeding system and kind of diet: a) diet L – restricted feeding; b) diet H – restricted feeding; c) diet L – *ad libitum*; d) diet H – *ad libitum*

and restored in the body) was too high as compared with their protein accretion ability and ultimately they were fatter and contained less protein in the body as compared with control pigs.

The pigs previously having a low daily energy intake and fed at a restricted level during realimentation still had a higher amount of protein in the body at target weight because their energy intake was too low to fully recover their body fat content (Figure 5). *Ad libitum* feeding of this group of pigs increased the intake of energy and as a consequence its distribution between protein and fat deposited in the body must be changed. Pigs fed in this way favoured fat to protein accretion in the body, which allowed them to decrease the protein content in the body to the level of control pigs and even to restore fat content before reaching 70 kg (Figure 5).

Data from literature concerning compensatory growth regarding the time taken to compensate chemical body composition of pigs are unclear. Sarkar et al. (1983) reported full recovery of chemical body composition up to 90 kg in pigs previously consuming daily low energy. On the other hand, Stamataris et al. (1991) did not obtain a compensation of chemical body components at 24 kg in pigs previously underfed from 6 to 12 kg. Data presented by Bikker (1994) also show that pigs underfed from 25 to 45 kg at the end of realimentation (80 kg) had still less fat and more protein and water in the body than normally fed animals.

In pigs previously fed a low protein diet (Fandrejewski, 1994) full compensation of chemical body composition was found at 60 kg. In contrast, de Greef et al. (1992) did not find recovery of chemical body components in pigs weighing 90 kg and previously underfed from 28 to 65 kg.

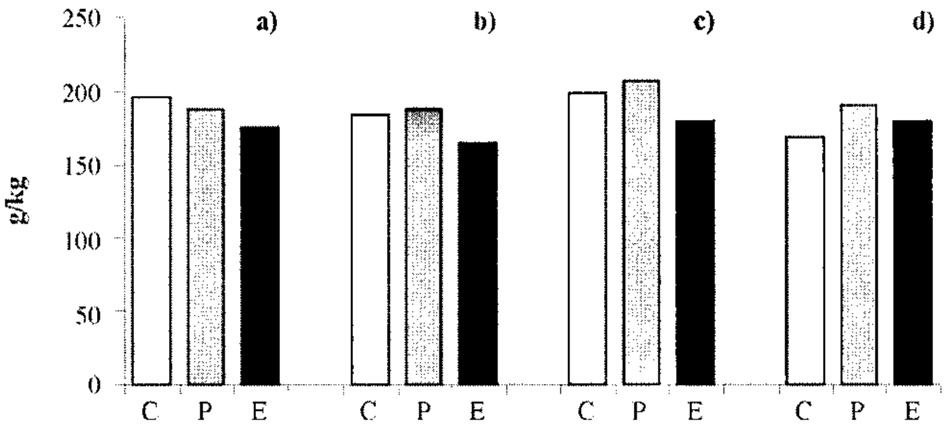

Figure 5. A fat content in the body of pigs at 70 kg body weight in respect to feeding system and kind of diet: a) diet L – restricted feeding; b) diet H – restricted feeding; c) diet L – *ad libitum*; d) diet H – *ad libitum*

A discrepancy of the results of cited studies is caused by different severity and duration of the restriction as well as duration of the realimentation period. Additionally, the animals differed in age and were underfed in a dissimilar way so the results of these works cannot be directly compared.

It should be pointed out that in our study, the body of pigs fed a diet with a high energy content (H) contained less fat and had a better fat:protein ratio in spite of their higher feeding intensity. This resulted from the improved lysine:ME ratio in this diet and from the response of the pigs indicating that young animals having a large growth capacity are much more sensitive to energy than protein (lysine) supply (Lawrence et al., 1994).

Considering the influence of feeding level on the fat:protein ratio in the body of pigs from particular groups, it could be pointed out that a change in *restricted* to *ad libitum* feeding did not increase the fat:protein ratio in the C pigs, but this value was considerably higher in the previously protein- (P) and energy- (E) restricted pigs. Such a response of pigs is probably caused by differences in the proportion of fat and protein deposited in the daily body gain of pigs previously underfed in both energy and protein terms. This fact should be taken into consideration in practice in the nutrition of pigs on which some nutritional restriction was previously imposed.

The greater mass of the gastrointestinal tract of pigs fed the diet with the lower energy content (L) resulted from the heavier weight of their liver. The main reason for the heavier liver mass of these pigs was probably the glucosinolate content in the L diet where rapeseed meal was the main source of protein (Thomke et al., 1998).

It was found that that the final weight of entrails and of some organs (the liver, small and large intestines) did not differ significantly between groups C, E and P. The lack of differences, especially in the E pigs, which had the lowest weight of entrails and intestines at 25 kg, indicated that this part of the body of these animals grew much faster as compared with the remaining groups. It also means that these pigs showed compensatory growth of their viscera. This phenomenon was also reported by Koong et al. (1985), Stamataris et al. (1991), Bikker (1994) in pigs previously underfed for energy, and by Ryan (1989) in a study on cattle.

CONCLUSIONS

Based on the results of this study it may be concluded that the growth rate of pigs is much more sensitive to energy than protein restriction in the diet. The kind of underfeeding influences the fat content in the body and pigs consuming inadequate amounts of energy have decreased, while those consuming inadequate amounts of protein have increased fat stores.

The growth of internal organs is much more sensitive to energy than protein restriction and the organs whose growth is most inhibited are the liver and small intestines.

Compensatory growth takes about 2-3 weeks after the change from restriction to realimentation and a recovery of body physical and chemical composition but not age of previously underfed animals is possible. However, the rate of recovery depends on the kind of recovering component and feeding intensity. An increase in feeding intensity during realimentation can considerably increase the fat:protein ratio in the body of both previously protein- and energy-underfed pigs, which should be taken into consideration in practice.

REFERENCES

AOAC, 1994. Association of Official Analytical Chemists. Officials Methods of Analysis. 15th Edition. Washington, DC

Bikker P., 1994. Protein and lipid accretion body components of growing pigs: effects of body weight and nutriem intake. PhD Thesis, Wageningen University (The Netherlands), pp. 1-203

Close W.H., Mount L.E., Brown D., 1978. The effects of plane of nutrition and environmental temperature on the energy metabolism of the growing pig. 2. Growth rate, including protein and fat deposition. Brit. J. Nutr. 40, 423-530

Fandrejewski H., 1994. Effect of protein intake on chemical body composition, size of internal organs and energy retention in growing pigs. Energy Metabolism of Farm Animals. EAAP Publication No. 76, 265-268

de Greef K.H., 1992. Prediction of production. PhD Thesis, Wageningen University (The Netherlands), pp. 1-117

Koong L.J., Ferrell C.L., Nienaber J.A., 1985. Assessment of interrelationships among levels of intake and production, organ size and fasting heat production in growing animals. J. Nutr. 115, 1383-1390

Kyriazakis L., Stamataris C., Emmans G.C., Whittemore C.T., 1991. The effects of food protein content on the performance of pigs previously given foods with low or moderate protein content. Anim. Prod. 52, 165-174

Lawrence B.V., Adeola O., Cline T.R., 1994. Nitrogen utilization and lean growth performance of 20 to 50 kilogram pigs fed diets balanced for lysine:energy ratio. J. Anim. Sci. 72, 2887-2895

Quiniou M., Dubois S., Noblet J., 1995. Effect of dietary crude protein level on protein and energy balances in growing pigs: comparison of two measurement methods. Livest. Prod. Sci. 41, 51-60

Ryan W.J., 1989. Compensatory growth in cattle and sheep. Nutr. Abstr. Rev., Ser. B. 60, 653-664

Sarkar N. K., Lodge G.A., Williams C.J., Elliot J.L, 1983. The effect of undernutrition of suckled pigs on subsequent growth and body composition after nutritional rehabilitation. J. Anim. Sci. 57, 34-42

Simon O., 1989. Metabolism of protein and amino acids. H.-D. Bock, B.O. Eggum, A.G. Low, O. Simon, T. Żebrowska (Editors). Protein Metabolism in Farm Animals - Evaluation, Digestion, Absorption and Metabolism. Oxford University Press, pp. 273-283

Stamataris C., Kyriazakis L., Emmans G.C., 1991. The performance and body composition of young pigs following a period of growth retardation by food restriction. Anim. Prod. 53, 373-381

Thomke S., Pettersson H., Neil M., Hakansson J., 1998. Skeletal muscle goitrin concentration and organ weights in growing pigs fed diets containing rapeseed meal. Anim. Feed Sci. Tech. 73, 207-215

Whang K.Y., McKeith F.K, Kim S.W., Easter R.A., 2000. Effect of starter feeding program on growth performance and gains of body components from weaning to market weight in swine. J. Anim. Sci. 78, 2885-2895

Yahya Z.A.H., Millward D.J., 1994. Dietary and the regulation of long bone and muscle growth in the rats. Clin. Sci. 87, 213-220

STRESZCZENIE

Wpływ okresowego niedoboru białka lub energii diecie na późniejsze cechy przyżyciowe i skład ciała rosnących świń

Doświadczenie przeprowadzono na siedemdziesięciu ośmiu loszkach rasy pbz o masie ciała 15 kg, podzielonych na 3 grupy (C, E, P). Świnie grupy C żywiono systemem dawkowanym, świniom grupy E obniżono o 40% pobranie energii, zwierzętom grupy P o 40% pobranie białka. Od 25 do 70 kg świnie wszystkich grup żywiono paszą o niskiej (L) lub wysokiej (H) koncentracji energii (12,4 lub 13,2 MJ ME, odpowiednio) podając paszę systemem dawkowanym (R) lub do woli (A). Zwierzęta ubijano przy 25 kg (12 szt.) i 70 kg (66 szt.), oznaczano skład chemiczny ciała, masę przewodu pokarmowego oraz wątroby, jelit cienkich i grubych. Od 15 do 25 kg świnie grup P i E rosły wolniej niż zwierzęta kontrolne (367, 242 vs 513 g/dzień). Przy 25 kg w 1 kg masy ciała netto świń grupy P było 185 g tłuszczu i 142 g białka, a masa wnętrzności była podobna jak u świń grupy C. W ciele zwierząt grupy E było 90 g tłuszczu i 163 g białka, a wnętrzności były o 12% lżejsze niż u świń grup C i P. Od 25 do 70 kg dzienne przyrosty świń oraz skład ciała przy 70 kg nie zależał od żywienia w okresie wzrostu od 15 do 25 kg. Tempo odbudowy poszczególnych składników chemicznych ciała od 25 do 70 kg zależało od intensywności żywienia i sposobu uprzedniego niedożywiania.

Stwierdzono, że wzrost kompensacyjny występował w pierwszych 2-3 tygodniach realimentacji oraz, że uprzednio niedożywiane zwierzęta są w stanie odbudować anatomiczny i chemiczny skład ciała.