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Growth of the gastrointestinal tract in weaning pigs as affected by crude fibre content in the diet*

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ABSTRACT

A growth of the gastrointestinal tract of weaned pigs as affected by crude fibre content in the diet was investigated on 16 piglets. Pigs of 10 kg body weight (BW) were offered a basal diet (group C and C_1) or diets formed by mixing a basal diet with 10 (diet GM_{10}) or 20% (diet GM_{20}) of grass meal (group F_1 and F_2, respectively). When pigs reached 25 kg BW animals of the groups F_1 and F_2 were offered a basal diet, whereas those of the group C_1 were offered diet GM_{20}, following 14 days. Afterwards, animals were slaughtered; mass of the stomach, small and large intestines was recorded. The pigs of the group F_2 consumed by 8.8% more feed compared with the C and C_1 pigs (1061 vs on average 979 g/day). However, the C and C_1 pigs grew faster (on average 535 g/day; P<0.01) than F_1 (462 g/day), and F_2 (443 g/day). A mass of the stomach of the both F_1 and F_2 pigs was insignificantly heavier (by 6.7 and 20.6%, respectively) as compared with the C pigs. Mass of the large intestines of the F_1 and F_2 pigs was also heavier (by 4.6 and 4.2%, respectively) but small intestine of these pigs was insignificantly lighter (6.7 and 12.3%, respectively). Length of the small intestines of the F_1 and F_2 pigs was lower (P<0.01; 32.3 and 30.1%, respectively), whereas length of their large intestine was unchanged. Correlation coefficients between previous fibre intake and mass of the stomach amounted 0.78 (P<0.009). However, a negative correlation between previous fibre intake and lenght of the small intestines (r= -0.68; P<0.06), as well as its weight (r= -0.45; P<0.07) were detected.

KEY WORDS: weaning pigs, alimentary tract, feed intake, grass meal, fibre

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INTRODUCTION

Recently, there has been renewed interest in keeping pigs outdoors due to public interest in animal welfare and more natural production systems (Edwards et al., 1996). In such maintenance condition roughage feeds are widely used.

However, pigs fed such feed, rich in fibre, during fattening period restrict their growth rate and deteriorate production efficiency. That's why feeding of pigs kept in outdoor system is modified very often and roughage (bulk feed) components are only temporary fed to animals or they are mixed with commercial feeds. One of the goals of these procedures is decrease a negative influence of dietary fibre on pig productivity.

Effect of dietary fibre on size/capacity of the gastrointestinal tract is well known mainly in growing animals over 25 kg body weight (Jin et al., 1993, 1994; Jørgensen et al., 1996). However, the role of dietary fibre in regulation of intestinal growth of newly weaned piglets is poorly understood. There is no common knowledge if weaned pig response in the same way as older ones, and what is a subsequent effect of feeding to weaned piglets a diet rich in fibre on the growth of their gastrointestinal tract after return to commercial feeding. Such knowledge would be useful in out-door/organic rearing system. Moreover, it could be used to work out the strategy of nutrition of pigs kept in such condition.

Therefore the objective of this study was to determine the effect of supplementation diet for newly weaned piglets with 10 or 20% of grass meal on the growth of their gastrointestinal tract.

MATERIAL AND METHODS

The experiment was carried out with 16 piglets (four litters of four gilts each). Piglets weaned at 4^{th} week of age and weighing approximately 8 kg, were transported to environmentally controlled experimental pig house and kept individually with free access to feed and water. Prior to start of the experiment pigs were adapted to the accommodation and overcome any post-weaning stress. This period lasted up to reaching 10 kg body weight (BW).

The experiment consisted of two periods: from 10 to 25 kg BW, and following 14 days to about 30-32 kg BW according to the scheme given in Table 1.

When piglets achieved 10 kg BW they were within litter allotted to C, C_1, F_1, F_2 groups and fed *ad libitum*. Pigs of the C and C_1 group were offered a control diet (B), whereas pigs of the F_1 and F_2 group were offered respectively diets, GM_{10} and GM_{20} formulated by mixing a diet B with 10 or 20% of grass meal, respectively. The feeds were analysed for gross energy, dry matter, crude protein, ether extract, ash,

TABLE 1

Experimental designe

Items	Groups			
	C (n=4)	F_1 (n=4)	F_2 (n=4)	C_1 (n=4)
10 - 25 kg	B	GM_{10}	GM_{20}	B
25 kg following 14 days	B	B	B	GM_{20}

B - control diet; GM_{10} - control diet diluted with 10% of grass meal; GM_{20} - control diet diluted with 20% of grass meal

crude fibre (AOAC 1994), acid-detergent fibre (ADF) according to Goering and Van Soest (1970) and neutral-detergent fibre (NDF), (Robertson and Van Soest, 1977). Chemical composition and nutritional value of the diets are given in Table 2.

TABLE 2

Chemical composition and nutritional value of diets (per kg diet)

Items	Diets		
	B	GM_{10}	GM_{20}
Chemical composition, g			
dry matter	873.9	873.8	882.1
ash	62.0	65.3	66.1
nitrogen	32.2	30.5	29.9
ether extract	22.6	23.6	24.3
crude fibre	37.9	53.5	76.4
ADF	6.8	8.5	10.7
NDF	32.8	39.3	44.5
N-free extractives	550.2	540.8	528.4
Nutritional value			
gross energy, MJ	16.7	17.3	16.8
metabolizable energy, MJ	12.3	11.7	11.2
crude protein, g	201	191	187

B - control diet; GM_{10} - control diet diluted with 10% of grass meal; GM_{20} - control diet diluted with 20% of grass meal

When pigs reached 25 kg BW animals of the F_1 and F_2 groups were offered the diet B and those of the group C_1 were offered a diet GM_{20} for 14 days. However, animals of the group C were still offered the diet B. The aim of this procedure was to check if expected changes in the size of gastrointestinal tract, provoked by high fibre intake, would be still lasting after returning to the commercial feeding. During that period all pigs were offered the same amount of feed (1.2 kg/day) to avoid an influence of individual variation in feed intake on factors that were investigated.

On 14 day following 25 kg BW animals were slaughtered, the abdominal cavity was opened and the entire gastrointestinal tract was removed. The stomach was insulated cut open along the greater curvature, emptied and weighed. The small and large intestines were removed, separated from mesenteric fat and recorded for length and mass.

Performance of pigs (feed intake, fibre intake, body gain and feed conversion ratio) was recorded during first period of the study. Feed consumption and body weight of pigs were recorded weekly. Feed consumption was calculated as a difference between the feed offered and those remained in the feeder.

Statistical analyses were performed by analysis of variance ANOVA and correlation analysis using the Statgraphics version 6.0 Plus software.

RESULTS

Supplementation of the diet B with grass meal resulted in increase of crude fibre content, ADF and NDF fraction causing a deterioration of nutritional value, especially metabolizable energy and protein/lysine content (Table 2).

Due to difference in fibre content in the diets, offered to the piglets, daily fibre consumption varied from 31.7 g (on average for group C and C_1) to 81.1 g (group F_2). Average daily feed intake from 10 to 25 kg BW did not differ significantly between groups of pigs (Table 3). Albeit, pigs of the group F_2

TABLE 3

Performance of pigs during growth from 10 to 25 kg

Group	Feed intake, g/day	Fibre intake, g	Average daily gain, g	Days	FCR, kg feed:gain
C	979	31.4	557	27	1.74
F_1	932	49.9	513	29	1.82
F_2	1061	81.1	471	32	2.25
C_1	970	32.0	570	27	1.70
SEM	21.86	1.46	15.45	1.24	0.04
Significance	ns	*	*	**	**

** for P<0.01; * for P<0.05; ns - difference insignificant; FCR - feed conversion ratio (kg/kg)

consumed on average 8.8% more feed compared with the C and C_1 pigs (1061 g vs 975 g/day). Pigs of the groups C and C_1 grew on average 564 g/day, those of the group F_1 513 g/day and F_2 471 g/day (P<0.05). Feed conversion ratio differed (P<0.01) between groups (1.72, 1.82, 2.25 kg/kg gain, respectively for group C, F_1 and F_2). Daily feed intake during the first week of the experiment was unaffected by experimental treatment (Table 4). During the second week both groups F_1 and F_2 was considerably lower (by 13.3 and 9.8%, respectively) as compared to average intake of the C and C_1 pigs. Through the third week feed consumption of the F_1 pigs was comparable to the C and C_1 pigs, whereas, in the group F_2 was even insignificantly greater. During next week the growth rate of pigs of F_1 and F_2 group did not differ significantly from the C and C_1 animals. The pigs of group F_1 needed 29, whereas those of group F_2 32 days to reach 25 kg BW comparing to on average 27 days for groups C and C_1. However, differences were significant only between groups C and F_2.

TABLE 4

Daily feed intake (DFI) and average daily gain (ADG) of pigs during following weeks of the growth from 10 to 25 kg BW

Group	Diet offered	Week of the experiment							
		1		2		3		4	
		DFI, g	ADG, g	DFI, g	ADG, g	DFI, g	ADG, g	DFI, g	ADG, g
C	B	640	480	890	537	1005	572	1140	686
F_1	GM_{10}	648	271	782	535	1025	600	1182	661
F_2	GM_{20}	650	211	814	429	1170	557	1196	625
C_1	B	620	480	914	537	1015	582	1160	670
SEM		41.25	40.77	86.11	71.79	95.76	27.66	91.33	27.20
Significance		ns	**	*	**	*	ns	ns	ns

** for P<0.01; * for P<0.05; ns - difference insignificant

Mass of the gastrointestinal tract (GT) of the pigs of the groups F_1 and F_2 did not differ significantly from the C and C_1 pigs (Table 5). Mass of the stomach increased (208, 209, 222 and 251 g, respectively for the C, C_1, F_1 and F_2 pigs), whereas mass of the small intestine decreased (979, 967, 913 and 858 g, respectively for the C, C_1, F_1 and F_2 pigs) along with grass meal supplement was increased. Large intestine of the F_1 and F_2 pigs was heavier as compared with the C and C_1 pigs (567, 565 vs on average 541 g, respectively). However, the differences were statistically insignificant. Small intestine of the pigs of F_1, F_2 and C_1 groups was shorter (P<0.01) as compared with the C pigs (920, 951 and 954 vs 1360 cm, respectively), whereas length of the large intestines did not differ significantly between groups.

Correlation coefficients between previous fibre intake and mass of the stomach was high and amounted 0.78 (P<0.009; Table 6). Lower and negative correlation between previous fibre intake and small intestines length (r= -0.68; P<0.06), small intestines weight (r=-0.45; P<0.07) were detected. No correlation between previous fibre intake and the length of the large intestines and its weight was found.

TABLE 5

Size of total gastrointestinal tract (GT), stomach and intestines of the pigs at the end of the study

	GT[1]	Stomach	Small intestine		Large intestine	
	G	g	g	cm	g	cm
C	1729	208	979	1360	542	352
F_1	1702	222	913	920	567	344
F_2	1675	251	858	951	565	350
C_1	1719	209	967	954	539	331
SEM	30.27	6.45	17.66	27.65	15.47	7.88
Significance	ns	ns	ns	**	ns	ns

[1] gastrointestinal tract = stomach+small intestine+large intestine; ns - difference insignificant; ** for P<0.01; * for P<0.05

TABLE 6

Correlation coefficient between previous crude fibre intake and weight of the stomach and weight/length of the small and large intestines

	Stomach weight	Small intestine		Large intestines	
		cm	g	cm	g
Fibre intake	0.78	-0.68	-0.45	0.20	0.23
P value	0.009	0.06	0.07	0.201	0.260

DISCUSSION

Slower average growth rate of the F_2 pigs resulted from the lowest protein digestibility of GM_{20} diet caused by fibre components (Buraczewska, 2001) as well as lower metabolizable energy content (Skiba et al., 2005). In consequence these pigs consumed significantly lower amount of digestible protein and energy as compared with the control animals. Increasing intake of feed as early as the third week of the experiment allowed the pigs to consume considerably more digestible protein and energy resulted in increased growth rate. Feed intake during following week of the experiment proved that pigs needed some period of time to adapt their gastrointestinal tract to intake of a diet with increased fibre content depending on it's supplement. Reason of this was physical structure of the diet including a bulk component. Fibre of such diet (especially non-starch polysaccharides) has a greater property to trap water, swell and form gels with high water contents (so-called water holding capacity). All of these phenomenons strongly limit intake of such feed (Tsaras et al., 1998). This limitation could took place in the stomach, when water intake accompanies the consumption of dry feed, as well as in the following part of gut, where water is retained throughout its passage along intestines (Eastwood et al., 1983). On the other hand, difference in physical structure between commercial and diet including a bulk component causes that even in the case of similar or slightly lower quantitatively consumption (kg/day) of diet including a bulk component (e.g., grass meal) animals in fact consume greater volume. This in combination with greater water-holding capacity of feed including bulk component does not have mean lower capacity of gastrointestinal tract of those pigs. These suggestion confirmed the results given by Kyriazakis and Emmans (1995), who reported no significant difference in feed intake (kg/day) between pigs fed commercial diet and those consumed the same diet diluted with wheat bran. However, gut fill of the pigs fed diets diluted with bulk component increased significantly if percentage share of bulk component in the diet increased (Whitemore et al., 2001).

Adaptation of gastrointestinal tract of our pigs to deal with "grass meal diet" occurred also through enlargement of the stomach, as highly significant positively correlation between it mass and previous fibre intake had been detected. Kyriazakis and Emmans (1995) reported also increased mass of the stomach resulted from increased fibre intake. This effect was more pronounced if dilution a basal diet with bulk component increased.

Our results indicate that small intestine tends to be lighter and shorter when animals consume greater amount of bulk feed. Shortening of the small intestine was observed already after 14 days consumption a grass meal diet, by the C_1 pigs during the second growth period of the experiment. It seems that shortening of the intestine could be connected with faster passage of chyme in animals fed fibrous diet (Goff et al., 2002) as muscular coat of the intestine contracts more intensively. Shorter and lighter small intestine was found also in animals previously fed a grass meal diet (F_1 and F_2 groups), what could mean that under influence of dietary fibre length as well as mass of this organ could be permanently changed.

Mass of the large intestines of older pigs is positively correlated with the amount of fibre consumed due to re-absorption of water as well as due to greater activity of the bacterial flora degrading nutrients trapped in the mixture of water and fibre (Rundgren, 1988). In our experiment the size of the large intestine was practically uninfluenced by the amount of fibre consumed, unlike to older pigs, as in the piglets its role in microbial fermentation is usually limited. However, it could be also dependent on composition of fibre added to the diets, particularly its soluble fraction (Venk, 2001).

After adaptation of gastrointestinal tract the pigs used in our experiment were even able to consume greater amount of grass meal diet as compared to pigs fed the control feed. Based on diets composition (degree of dilution with grass meal) it was calculated that during last week of the experiment pigs fed diets diluted with grass meal consumed almost the same amount of the diet B and an extra 108 g (group F_1) and 239 g (group F_2) of grass meal. Converting these values for intake of fresh grass, base on dry matter content, it intake would be of 475 and 1050 g in the pigs of 25 kg BW. Sparse literature data shown that herbage intake by growing pigs depends on supplying of concentrate feed. Growing pigs (50-60 kg BW) consumed only 500 g of fresh ryegrass-white clover sward when also they were offered *ad libitum* concentrate (Mowat et al., 2001). In the other study (e.g., Carlson et al, 1999) a value of 830 to 2298 g/day of grass-clover herbage was recorded in pigs from 40 to 70 kg BW. When concentrate was offered restrictively (70% of normal allowances) pigs from 27 to 100 kg BW consumed 1100 g of fresh grass-clover herbage (Danielsen et al., 1999). However, it is difficult to compare of cited results to our value due to difference in fibre level and its composition and age of animals as all strongly influence intake of roughage components.

Described changes in gastrointestinal tract indicate that intensity of the response to bulk feed depends on amount and kind of their fibrous component in the diet fed to pigs. Simultaneously, our results indicate that weaned pigs have a great adaptable ability and can fit their gastrointestinal tract to nutritional regimen and kind of consumed diet very quickly. Consuming greater amount of feed diluted with roughage component pigs try to maintain a constant energy and nutrients intake to cover their needs (Frank et al., 1983). However, our results are in disagreement with suggestion given by Black et al. (1986), that pigs weighing less than 20 kg are unable to increase feed intake to compensate energy intake when it's content in the diet is below 16 MJ DE/kg diet. As DE content in both grass meal diets, applied in our experiment, was much lower than value given by authors cited above.

CONCLUSIONS

Supplementation of diet with fibre component decreases amount of available nutrients and in consequence reduces growth rate of animals. Albeit, even very young pigs are able to adapt to such kind of diet by increasing feed intake what needs some period of time, but it duration depends on fibre content in the diet. Increasing feed consumption piglets try to maintain a constant energy and nutrients intake to cover their growth requirements. Other symptoms of adaptation are anatomical changes of gastrointestinal tract. Long-lasting (approximately 4 weeks) feeding to piglets a high fibre diet increases, like in older pigs, mass of their stomach. However, unlike to the older animals, small intestine tended to be shorter and lighter, probably due to faster transit of chyme along gastrointestinal tract. Size of the large intestine was uninfluenced, as probably its role in digestive process in young piglets is limited or composition of the used fibre component did not support bacterial fermentation in this part of gastrointestinal tract. Our results prove that mentioned changes in anatomical composition of gastrointestinal tract are held up even after return to feeding with commercial diet. Results indicate also that to avoid a deterioration of fattening performance of pigs reared in outdoor conditions they should be previously adapted to the kind of diet which will be consumed.

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STRESZCZENIE

Rozwój przewodu pokarmowego odsadzonych prosiąt w zależności od ilości włókna w paszy

Doświadczenie obejmowało dwa okresy wzrostu świń: od 10 do 25 kg oraz od 25 kg przez kolejne 14 dni. Od 10 do 25 kg świnie grup C i C_1 żywiono paszą kontrolną (B), świnie grupy F_1 i F_2 otrzymywały odpowiednio diety GM_{10} i GM_{20} utworzone przez dodanie do paszy B 10 lub 20% suszu z traw. Od 25 kg zwierzęta grup F_1 i F_2 karmiono paszą B, zwierzęta grupy C_1 pobierały mieszankę GM_{20}. Po 14 dniach zwierzęta ubito, oznaczono masę żołądka oraz masę i długość jelita cienkiego i grubego. Cechy przyżyciowe badano w okresie wzrostu od 10 do 25 kg m.c. Prosięta grupy F_2 pobierały o 8,8% więcej paszy w porównaniu z prosiętami grupy C i C_1 (1061 g vs 979 g/dzień). Zwierzęta grup C i C_1 rosły szybciej (535 g/dzień, $P<0{,}01$) niż świnie grup F_1 (462 g/dzień) i F_2 (443 g/dzień). W porównaniu ze zwierzętami grupy C masa żołądka prosiąt grup F_1 i F_2 była większa (o 6,7 i 20,6%, odpowiednio), podobnie masa jelita grubego (o 4,6 i 4,2%, odpowiednio), natomiast masa jelita cienkiego była nieistotnie mniejsza (o 6,7 and 12,3%). Długość jelita cienkiego świń grup F_1 i F_2 była mniejsza ($P<0{,}01$) w porównaniu ze zwierzętami kontrolnymi (odpowiednio o 32,3 and 30,1%), a długość jelita grubego była podobna. Współczynniki korelacji pomiędzy ilością uprzednio pobieranego włókna a końcową masą żołądka wynosił $r=0{,}78$ ($P<0{,}009$). Stwierdzono również ujemną korelację pomiędzy ilością uprzednio pobieranego włókna a długością jelita cienkiego ($r=-0{,}68$; $P<0{,}06$) oraz masą jelit cienkich ($r=-0{,}45$; $P<0{,}07$).