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Pure cellulose as a feed supplement for piglets

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Summary

The effects of supplementing piglets' feed with pure cellulose on their health condition, rearing results and some features of the alimentary tract was determined on 207 piglets allocated to 4 experimental groups. All piglets were fed the same feed mixture which was supplemented with different amounts of cellulose. Groups I, II, III, IV received mixtures with 0, 1.5 or 2.0% of cellulose, respectively. Feed mixtures were available ad libitum since day 7 of age. At day 35 the piglets were weaned and fed restricted amounts of feed. Between days 52 and 58, 4 piglets from each group were slaughtered and fragments of the small intestine were extracted for morphological measurements. Microbiological tests were made on small intestine and caecum digesta and the content of volatile fatty acids was estimated. The experiment was completed on day 84 of the piglets' life. It was found that cellulose improved piglets' health and performance indices. There were 25 cases of diarrhea noted in the control group and only 8 cases in the group receiving 2% of cellulose. Body weight gains in these groups during the whole experiment were 256 and 274 g per day, respectively. The lowest number of E. coli and Clostiridium was observed in the digesta of the small intestine and caecum of piglets receiving the highest supplement of pure cellulose. The total amount of all estimated volatile fatty acids was lower in the control group when compared with the experimental ones. The ratio of the villus height/crypt depth was 0.842 in control animals and 1.119 in groups III and IV. It was concluded that even a small amount (1.5-2.0%) of insoluble fiber in piglets' feed can improve their health and performance, which may be due to changes in the gut morphology, digesta acidity and lower number of harmful bacteria present in the intestine.

Keywords: piglets, nutrition, cellulose, intestine morphology, microflora

Fiber is an important component of feed. It affects feed consumption, digestion and absorption of nutrients (20). It also can change the composition of the alimentary tract microflora (8) and gut morphology (12). Solubility is an important feature of fiber: soluble fibers elongate the time of the digestive passage through the alimentary tract and lower nutrients absorption, while insoluble ones shorten the passage time (15). Hedemann et al. (7) in their experiment on young pigs found that insoluble fiber improved gut morphology by increasing villi length and increased mucosal enzyme activity when compared with pigs fed soluble fiber (pectin) containing diets. Their results also suggest that pigs fed high insoluble fiber diets might be better protected against pathogenic bacteria than pigs fed diets rich in soluble fiber. Weaning of piglets is frequently accompanied by diarrhea which is usually due to bacteria proliferating in the alimentary tract, mainly *Escherichia coli.* According to McDonald et al. (13) and Hopwood et al. (8) soluble fiber supports bacteria development while according to Bertschinger and Eggenberger (2) insoluble fiber has an antibacterial effect. Insoluble fiber is decomposed by bacteria in distant parts of the alimentary tract and short chain fatty acids are produced (10). A greater production of these acids can have health related effects (21), but the main insoluble fiber – cellulose is less digestible for piglets than for adult pigs (15).

The aim of the study was to determine the effects on the health condition, rearing results and some features of the alimentary tract of piglets whose feed had been supplemented with pure cellulose.

Material and methods

The experiment was performed on 207 piglets originated from 20 sows (Polish Landrace × Large White Polish), mated with Pietrain × Hampshire boar. After farrowing, piglets were allocated to the experimental groups. Each experimental group consisted of 5 litters i.e. 50-54 piglets. Feed mixtures were available *ad libitum* for all piglets from day 7 of age. At day 35 all piglets were weaned, every litter was kept in a separate straw bedded pen and fed restricted amounts of feed mixture. Because of the experimental conditions they were fed the same feed mixture for the whole

Tab. 1. Composition and nutritive value of feed mixture

Components	Content (%)			
Barley, ground	32.00			
Wheat, ground	22.00			
Corn, ground	10.00			
Rapeseed meal	6.00			
Soybean meal	20.00			
Dried whey	5.00			
Rapeseed oil	2.00			
Dicalcium phosphate	1.00			
Limestone	1.00			
Salt (NaCl)	0.30			
Premix PP-prestarter *	0.50			
L-lysine	0.20			
Content of nutrients in 1 kg of mixture				
Dry matter (g)	888.10			
Metabolizable energy (MJ)	12.80			
Crude protein (g)	195.00			
Crude fat (g)	35.50			
Crude fibre (g)	55.10			
Crude ash (g)	51.80			
N-free extractives (g)	550.70			
Lysine (g)	11.20			
Methionine + cystine (g)	6.70			
Threonine (g)	8.40			
Tryptophan (g)	2.70			
Calcium (g)	8.34			
Phosphorus (g)	6.46			
Fibre fractions	Group I	Group II	Group III	Group IV
NDF (%)	19.98	18.57	19.48	22.50
ADF (%)	6.19	6.52	7.09	7.64
ADL (%)	0.54	0.17	0.20	0.22

Explanations: * – premix composition: vitamin: A – 2 700 000 IU; D3 – 400 000 IU; E – 8.0 g; K3 – 0.5 g ; B_1 – 0.5 g; B_2 – 0.8 g; B_6 – 0.8 g; B_{12} – 0.008 g; pantothenic acid – 2.8 g; choline cloride – 70 g; folic acid – 0.2 g; nicotinic acid – 5.0; magnesium – 10 g; manganese – 12 g; iodine – 0.1 g; zinc – 30 g; iron – 20 g; copper – 32 g; cobalt – 0.06 g; selenium – 0,04 g; complete limestone to 1000 g

rearing period, but its daily amounts were related to the piglets' body weight. The experiment lasted until day 84 and the individual body weight of piglets was recorded at day 1, 35, 56 and 84. The piglets' condition was observed, feed intake of each litter was measured and feed utilization was calculated. The animals had free access to water.

The piglets were fed with a standard mixture (tab. 1) with no supplement in group I (control) or supplemented with different amount of cellulose: 0.5, 1.5 and 2.0% in group II, III and IV, respectively. The source of cellulose was a commercial preparation Vitacel R 200 – a concentrate of pure cellulose made from coniferous trees.

The content of nutrients in the feed mixture was determined according to AOAC (1) methods. Fiber fractions were estimated according to Goering and van Soest (6).

Between the 52^{nd} and 58^{th} day of age 16 piglets (4 from each treatment) were slaughtered and a fragment of their small intestine extracted to determine the height and width of villi and measure the crypts. The extracted material was fastened to polystyrene plates and fixed in 10% buffered solution of formalin. Lengthwise strips, two for each specimen were taken. They were transformed using the Shandon company tissue processes and embedded in paraffin. Sections of 3 mm were made from the paraffin blocks and dyed using the hematoxylin-eosin method. Only the villi with uniform fibro vascular stroma were used in the measurement i.e. they were cut along the lengthwise axis. For each villi 3 longitudinal and 3 transversal measurements were made using the AnalySIS computer system. Activation of the images was made with Zeiss Anxioscop microscope and CCD ZVS-47DE camera. Microbiological tests were carried out on the caecum and small intestine digesta. The presence of aerobic bacteria, especially *Escherichia coli* and anaerobic ones, and, *Clostridium sp.* in particular, were determined. The presence of yeasts and moulds was also estimated. The tests were made using agar medium by bioMerieux. Volatile fatty acids content of ceacum contents was estimated using the VARIAN 3400 gas chromatograph.

The obtained data were analyzed statistically by analysis of variance, and significance of differences was examined using the Duncan's test (Statistica Software, 1995).

Results and discussion

The piglets rearing results (tab. 2) indicate that cellulose supplementation improved piglet health and rearing performance. This supplement resulted in lower diarrhea incidences and a lower mortality rate. The higher the supplement of cellulose received, the better the piglets' health. While 6 piglets from the control group died or had to be withdraw from the experiment, only one piglet was withdrawn from the group receiving 2% of cellulose. Incidences of diarrhea were noted in 25 and 8 piglets, respectively. Unfortunately, not much data on the effect of cellulose on piglet's health and performance is available. It may be supposed that this positive effect was due to changes in bacterial flora present in the piglets' alimentary tract. Such a health-related effect of fiber was found by Vanderhoof et al. (17) in cases of acute diarrhea in infants. Also Correa-Matos et al. (4) found beneficial effects of fermentable fiber (soy polysaccharides) in piglets infected with *Salmonella typhimurium*. Generally it can be stated that bacterial degradation of dietary fiber to short chain fatty acids (SCFA) is essential in maintaining small bowel and colonic mucosal structure and function (3).

Bacteria colonizing the gastro-intestinal tract of newly born piglets include mainly *Lactobacilli*, *Esche-*

richia coli, *Streptococci* and *Clostridia* (14). *E. coli* and *Clostridia* were also found in this experiment. According to Montagne et al. (15) diets containing less fiber – thereby limiting the amount of fermentable substrate result in less accumulation of such substrate in the small intestine – the primary site of the pathogenic *E. coli* proliferation. In this experiment no such proliferation was found though the number of bacteria had changed (tab. 3). Mainly anaerobic ones were found. In small intestine the number of *Clostridium* in 1 g of digesta fell from 1.82 in the control to 0.52 in group IV. The corresponding numbers in the caecum content were 2.90 and 1.67. This is partly in accordance with the finding of Owusu-Asiedu et al. (16) where a soluble fiber (guar gum) rather than insoluble ones (cellulose) increased ileal Clostridia.

Differences in the number of bacteria present in the alimentary tract of piglets were not consistent with changes in the acidity of digesta. The content of almost all the analyzed acids in the caecum of piglets from all groups was similar, though the total of all estimated acids was lowest in the control group (tab. 4). Significant differences were found only in acetic acid content between group III and the control. Small differences in volatile fatty acids content are reflected in similar pH values. There was a significant difference only between group I (pH 5.21) and group II (pH 5.61). The digesta in caecum of piglets receiving the smallest dose of cellulose was even less acidic than that of the control animals. Högberg (9) found a lower pH in the small and large intestines of pigs receiving high non-starch polysaccharides diets but she used cereal fiber, not pure cellulose. The low content of short-chain fatty acids and relatively high pH in the caecum of growing-finishing pigs fed with preparations of cellulose when compared to those fed with guar gum was found by Furgał-Dierżuk (5). Decreased caecal pH after giving pure cellulose was, however, found in rats (11). As far as the small differences in acidity of the small intestine and its bacteria content in our trial, other factors were most probably the reason for health-related effects of cellulose. One such factor could be the morphology of the small intestine.

Tab. 2. Indices of sows' reproductive performance and piglets' rearing

Performance indices	Group I	Group II	Group III	Group IV	SEM
Reproductive performance of sows					
No of litters in treatment	5	5	5	5	–
No of born piglets in treatment	50	54	52	51	–
Average No of piglets born per litter	10.0	10.8	10.4	10.2	–
Average No of piglets weaned per litter	9.4	10.4	10.2	10.2	–
Average No of piglets at 84th day per litter	8.8	9.8	9.8	10.0	–
Dead and culled piglets (No)	6	5	3	1	–
Dead and culled piglets (%)	12.0	9.2	5.7	2.0	–
Number of diarrhoea of piglets	25	19	17	8	–
Piglets' performance					
Body weight (kg) in days of age:					
1st	1.46[a]	1.54[ab]	1.45[a]	1.59[b]	0.019
35th	7.95[a]	8.07[ab]	8.37[ab]	8.76[b]	0.094
56th	11.44[a]	11.85[ab]	12.26[ab]	12.54[b]	0.185
84th	22.70	23.54	24.84	24.32	0.398
Average daily gain (g) in periods of life:					
1st-35th day	190[a]	187[a]	203[ab]	210[b]	2.88
35th-56th day	163	180	185	180	6.09
56th-84th day	402	417	449	420	10.57
35th-84th day	300	315	336	318	7.42
1st-84th day	256	265	282	274	4.84
Feed intake (kg/head/day) in periods of life:					
1st-35th day	0.031	0.034	0.035	0.034	0.001
35th-56th day	0.280	0.317	0.348	0.337	0.011
56th-84th day	0.867	0.932	0.948	0.964	0.024
35th-84th day	0.613	0.685	0.661	0.701	0.016
1st-84th day	0.380	0.418	0.403	0.429	0.008
Feed conversion ratio (kg/kg) in periods of life:					
1st-35th day	0.166	0.198	0.140	0.166	0.012
35th-56th day	1.825	1.866	1.889	1.757	0.096
56th-84th day	2.226	2.411	2.177	2.260	0.104
35th-84th day	2.106	2.254	2.030	2.116	0.094
1st-84th day	1.521	1.639	1.458	1.482	0.052

Explanations: a, b – mean values in the same row with different letters differ significantly at $P \leq 0.05$

It is known that dietary fiber which increases the villus height/crypt depth ratio might increase the absorptive capacity of the small intestinal epithelium (15). Such a difference in this parameter was found in this experiment: it rose from 0.842 in the control group to 1.12 in groups III and IV (tab. 5). According to Vente-Spreeuwenberg et al. (18) villus height decreases after weaning, which could be a result of lowered feed intake (19). Since the digestive enzymes' activity increase markedly from the bottom of the crypt

Tab. 3. Intestine digesta microbiology (Log $_{10}$ CFU/1g chyme)

Microorganisms	Group I	Group II	Group III	Group IV	SEM
Small intestine chime:					
No of aerobic bacteria	5.87	6.13	5.98	5.50	0.106
– including *E.coli*	4.38	4.82	4.83	4.15	0.133
No of anaerobic bacteria	2.61^{b}	1.85^{ab}	1.36^{a}	1.31^{a}	0.164
– including *Clostiridium*	1.82^{b}	1.06^{ab}	0.96^{ab}	0.52^{a}	0.176
No of *Candida*	3.21^{a}	4.00^{b}	3.29^{a}	3.08^{a}	0.354
No of moulds	2.33	2.50	2.37	2.22	0.066
Caecum chyme:					
No of aerobic bacteria	6.88	7.60	7.48	6.59	0.179
– including *E.coli*	5.13^{b}	4.92^{ab}	5.12^{b}	4.40^{a}	0.109
No of anaerobic bacteria	4.73^{b}	3.59^{a}	4.54^{b}	4.23^{ab}	0.148
– including *Clostiridium*	2.90^{b}	2.37^{ab}	2.74^{b}	1.67^{a}	0.167
No of *Candida*	3.06^{ab}	3.31^{b}	3.01^{ab}	2.82^{a}	0.295
No of moulds	2.61^{ab}	2.85^{bc}	2.92^{c}	2.47^{a}	0.061

Explanations: a, b, c – mean values in the same row with different letters differ significantly at $P \leq 0.05$

Tab. 4. Acidity and content of volatile fatty acids (µmol/1 g) in piglets' caecum chyme

Acid	Group I	Group II	Group III	Group IV	SEM
Acetic	45.44^{a}	54.12^{a}	63.99^{b}	53.61^{a}	2.193
Propionic	38.09	38.06	39.59	39.65	0.841
Butyric	23.81	25.48	23.18	25.29	1.258
Isobutyric	0.281	0.383	0.380	0.334	0.024
Valeric	9.211	9.730	5.130	8.540	0.803
Isovaleric	0.243	0.332	0.313	0.262	0.071
pH of small intestine chyme	5.88	6.00	5.69	6.17	0.11
pH of caecum chyme	5.21^{a}	5.61^{b}	5.34^{ab}	5.38^{ab}	0.06

Explanations: as in tab. 2.

Tab. 5. Small intestine morphological characteristics

Jejunum morphology	Group I	Group II	Group III	Group IV	SEM
Villus height (µm)	308^{a}	280^{a}	339^{b}	348^{b}	8.68
Villus width (µm)	139^{c}	128^{b}	125^{a}	135^{bc}	1.72
Crypt depth (µm)	366^{b}	341^{ab}	303^{a}	311^{a}	8.25
Villus height/Crypt depth	0.842	0.821	1.119	1.119	–

Explanations: as in tab. 3.

to the tip of the villus, a longer villus may enable better feed utilization. It promotes higher body weight gains, which were noted in this experiment. Hedemann et al. (7), who used higher doses of fiber (up to 145 g per kg of feed) than those used in this experiment, also found improved gut morphology and increased mucosal enzyme activity, which suggested that piglets fed high insoluble fiber diets might be better protected against pathogenic bacteria.

Summing up the obtained results, it can be stated that even a small amount (1.5-2.0%) of insoluble fiber in piglet diets can improve their health and performance. This may be due to the combined result of changes in gut morphology, digesta acidity and the lower number of harmful bacteria present in the intestine.

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