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THE EFFECT OF DIETARY MANNAN-OLIGOSACCHARIDE SUPPLEMENTATION ON THE DIGESTIBILITY OF NUTRIENTS, CHANGE OF IMMUNE STATUS AND GROWTH PERFORMANCE OF WEANED PIGLETS

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CONTENT

1. BACKGROUND AND THE OBJECTIVE OF THE RESEARCH

The complex stress factors associated with weaning cause a setback in the growth rate of pigs, and in more severe cases the increased prevalence of diarrhea and higher mortalities aggravate production losses further. Growth promoting antibiotics used to be an efficient and economical tool for mitigating such losses, but since they present a food safety risk these feed additives cannot be used in pig production anymore.

Numerous studies suggest that mannan-oligosaccharide products can be used as potential alternatives for growth promoting antibiotics. Although there has been an increase in the number of studies and literature reviews dealing with MOS, the simultaneous investigation of the mode of action of these products and their impact on pig performance is scarce and cursory in the literature. The acronym MOS means mannan containing carbohydrates, but the composition (chemical bonds) of these products varies and their efficiency in the different biological processes may vary as well. Because MOS products reduce the number of gastrointestinal pathogens and alter the immune response, they can be used to improve the performance of animals kept under poor hygienic conditions. In addition, MOS containing diets are associated with faster intestinal maturation in young animals, reducing the prevalence of impaired digestion occurring in pigs at weaning. All of these provide a basis for the potential growth promoting effect of MOS products, which is especially significant in animals performing below their genetic potential.

Although several scientific publications conclude that the MOS supplementation of diets enhances the growth performance of weaned pigs, few discuss the changes of nutrient digestibility as a result of MOS supplementation. The impact of dietary mannan-oligosaccharides on N-

retention is another area insufficiently covered in the literature. That is to say, if animal performance can be improved by increasing the mannan level of the diet, the question raises whether this is in consequence of the better digestibility of nutrients in the small intestine and/or of the more efficient N metabolism. It is also apparent from the relevant literature, that the mode of action of MOS products as immune-modulators has not yet been sufficiently clarified. Although the number of publications in this area is continuously increasing, only a few have provided parallel studies of cellular and humoral, and of specific and non-specific immune responses.

The comparison of published studies conducted with mannan-containing feed additives is difficult, because the authors rarely disclose the active ingredient content. Most studies contrast the control treatments with one trial treatment, in which the level of the mannan-containing product is between 1 and 5 g/kg. The conflicting results could also possibly be explained by the dose-dependent response to MOS, but this has been investigated by very few researchers only. A considerable number of published MOS studies were conducted in the US, where in accordance with the local practice piglets weaned at the age of 2-3 weeks were studied in most of the cases. As the time of weaning is vitally important for the morphologic and functional development of the gastrointestinal tract and also for the immunocompetence of the piglets, it is a significant question how the MOS supplementation of the diets influences nutrient digestibility and the immune response and performance of animals if weaning takes place at day 28 of age as is common in Hungary and in the European Union.

RESEARCH OBJECTIVES

The aim of the studies presented in these theses is to investigate for new data how the different dosages of mannan-oligosaccharide supplementation added to the diets of weaned pigs effect the:

(1) apparent ileal digestibility of nutrients in the diets fed;

(2) N retention of weaned pigs;

(3) non-specific and specific cellular, and the specific humoral immune response of weaned pigs; and

(4) the performance of animals during the nursery phase.

2. MATERIALS AND METHODS

Four trials were set up to answer the questions identified as the research objectives, namely: 1) digestibility study; 2) N metabolism study; 3) immunology study; and 4) performance study.

2.1. Digestibility study

The digestibility studies were conducted with a total of 30, simple T-cannulated, Hungarian Large White x Danish Landrace F1 barrows, weaned at 28 days of age, in two replicates (n = 6/treatments). The animals were individually housed in metabolism crates.

The digestibility studies comprised five treatments. The first of these being the negative control it contained neither mannan-oligosaccharide supplementation, nor growth promoting antibiotics (M0). The second, third and fourth treatments consisted of the basal diet plus a mannan-oligosaccharide supplementation (Agrimos, Lallemand, Blagnac, France), at the rate of 1, 2 and 4 g/kg, respectively (M1, M2, and M4 corresponding to the dosage of the mannan product). In the fifth group (positive control) the basal diet of the animals was supplemented with the growth promoting antibiotic Maxus-200 at the rate of 0.2 g/kg (40 mg/kg Avilamycin; Eli Lilly and Co. Ltd., Liverpool, United Kingdom) (AB).

In the digestibility study the trial animals were surgically fitted with simple T-cannulas at the terminal part of the ileum. The post-operative recovery period lasted for 5 days, thus the digestibility trial started when the animals were 35 days old. The 9 days adaptation period was followed by a 5 days collection period. During the collection period chyme was collected at 1, 3, 5 and 7 hours after feeding on the first-, third- and fifth days, whereas on

the second and fourth days samples were taken at 2, 4, 6 and 8 hours after feeding.

The nutrient content, including crude protein, crude fat, crude fibre, crude ash and N-free extract, plus Ca, P and Cr content of the diets and chyme samples were determined according to the AOAC (1989) procedure, while their amino acid content was analyzed according to Bech-Andersen et al. (1990). The effects of dietary treatments and replicates on the digestibility of nutrients were analyzed by variance analysis (SAS, 2004)

2.2. N balance study

A total of 48 Hungarian Large White x Danish Landrace F1 barrows, weaned at 28 days of age, were used in two replicates (n=9-10/treatment) in the N balance studies. The animals were taken from the same stock as the pigs used in the digestibility studies. Animals were housed in individual metabolism crates for the duration of the trial. The dietary treatments and the trial diets of the N balance studies were the same as those applied in the digestibility studies (M0, M1, M2, M4, AB).

In the course of the trial a 7 days adaptation period was followed by the 5 days collection period, during which the total quantity of faeces and urine was weighed to gram precision and recorded daily. Animals were fed the diets *semi ad libitum* (restricted in time), while drinking water was freely available. Feed intakes were recorded daily; the live weight of animals was read at the start of the adaptation period, and at the start and end of the collection period. The laboratory analyses of the diets and the statistical analysis are the same as those described in section 2.1. The N content of faeces and urine samples was determined.

2.3. Immunology study

A total of 58 Hungarian Large White x Danish Landrace F1 barrows, weaned at 28 days of age, were used in two replicates; the trial began at 35 days of age of the animals. The animals were taken from the same stock as the pigs used in the digestibility studies. The trial animals were housed in individual crates.

In the immunology study the animals were divided into 6 groups; pigs in five groups were immunized, pigs in group 6 were not immunized. Pigs in the immunized groups were fed one of the five dietary treatments used in the digestibility study (M0, M1, M2, M4, AB), while the non-immunized pigs (NI) were fed the diet without supplementation (M0). The non-immunized group was used in the trial as the control for immunization. In order to measure the specific cellular and humoral immune response the animals belonging to groups 1 – 5 were immunized on day 1 and 15 of the trial (days 35 and 49 of age) using inactivated Aujeszky vaccine (AyV) (Auphyl Plus, CEVA-Phylaxia). Blood samples taken from each animal on day 1 of the trial (day 35 of age), and then weekly on the same day and at the same time for 5 weeks were used to conduct serology and immunology tests. This was followed by the assessment of the specific local immune response, for the purpose of which pigs in groups 1 – 5 were challenged *per os* with a gastroenteritis virus (TGE) during week 8 of the trial. Following slaughter a 5 cm long intestinal loop sample was taken from the same parts of the small intestine, i.e. the midsection of each of the duodenum, jejunum and ileum of each animal.

The trial was conducted in two replicates, and the replicates took place at different times. The trial schedule is shown in Figure 1.

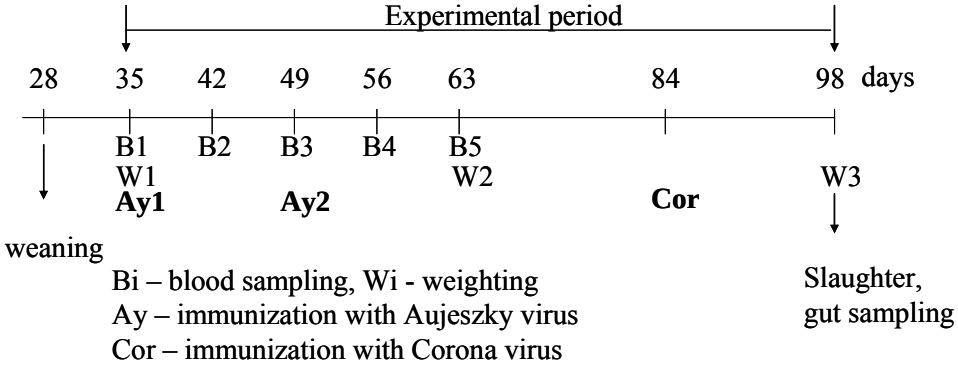

Figure 1: Time schedule of the experiment

The chemical tests of the diets were the same as those described under section 2.1. Cellular immunity was monitored using lymphocyte stimulation tests (LST). Immune functions were characterized by the changes of the lymphocyte blastogenesis. Stimulants used were phytohemagglutinin (PHA), concanavalin A (Con A) and pokeweed mitogen (PWM) as non-specific mitogens, and AyV as specific mitogen. The systemic humoral immune response of the pigs was measured on the basis of specific antibodies produced against Aujeszky disease (AyV), using a virus neutralization test (VN). The quantity of antibodies against local TGEV was determined using fixed cell ELISA. Statistical analysis of the data was performed according to the method described under section 2.1.

2.4. Performance study

The effect of dietary MOS supplementation on pig performance was studied in an on-farm trial. The trial was set up with a total of 324 Hungarian Large White x Danish Landrace F1 pigs of mixed sex (50% barrows, 50% gilts) weaned at 28 days of age, and originating from the same stock as the pigs used in the previous trials. Pigs were housed in flat deck pens in groups

(18 pigs/group); six pens were assigned to each dietary treatment (108 pig/treatment). Feed and water were offered ad libitum during the whole duration of the trial.

Three dietary treatments were used in the performance study. The diet fed to the negative control group (M0) contained no MOS or antibiotic supplementation; the diet of the positive control group (AB) contained 0.2 g/kg Maxus-200 (40 mg/kg Avilamycin); the animals of the trial group (M2) received 2 g/kg Agrimos supplementation in accordance with the recommendation of the manufacturer. The study was conducted during the 31-day period following weaning. In the course of the study the animals were weighed individually at the start of the study, on day 15 and at the end of the study, on day 31. Feed intake was recorded by pens; the feed conversion rate was computed separately for each group. The statistical analysis of the data was performed with one-way ANOVA (SAS, 2004).

3. RESULTS

3.1. The effect of dietary mannan-oligosaccharide supplementation on the apparent ileal digestibility of nutrients in weaned pigs

The effect of mannan-oligosaccharide supplementation of the diet on the apparent ileal digestibility of specific nutrients is shown in Table 1.

Table 1: The effect of dietary MOS supplementation on the apparent ileal digestibility of nutrients (%)

	T R E A T M E N T S *					**RMSE**
	M0	**M1**	**M2**	**M4**	**AB**	
	n = 6	n = 6	n = 6	n = 6	n = 6	
Dry matter	76.4^{b}	77.3^{ba}	79.2^{a}	77.9^{ba}	77.2^{ba}	1.9
Crude protein	72.5^{c}	73.6^{bc}	77.5^{a}	76.3^{ba}	77.5^{a}	2.0
Crude fat	93.9	93.0	93.8	93.8	94.1	0.8
Crude fibre	50.7^{a}	48.9^{a}	52.3^{a}	48.7^{a}	19.8^{b}	7.9
N-free extract	79.6	80.7	81.2	80.9	79.8	2.3
Calcium	47.1^{b}	55.5^{a}	54.2^{ab}	53.9^{ba}	50.2^{ab}	5.1
Phosphorus	55.1^{b}	62.8^{a}	64.7^{a}	65.2^{a}	61.0^{a}	3.2

* M0: negative control without antibiotic or MOS; AB: antibiotic treatment with 0.2 g/kg Maxus-200 (40ppm avilamycin supplementation); M1: supplementation of 1 g/kg MOS; M2: supplementation of 2 g/kg MOS; M4: supplementation of 4 g/kg MOS

$^{a, b}$ $P \leq 0.05$; RMSE: Root mean square error

Our results indicate that the apparent ileal digestibility of crude protein was 72.5% in the negative control group (M0), which improved by about 5% ($P \leq 0.05$) in the positive control (AB). The ileal digestibility of crude protein

improved also in consequence of the MOS supplementation, and a significant difference was found between the negative control and the diet that included 2 g/kg MOS supplementation. The further increase of the MOS dosage however did not lead to any further improvement in protein digestibility. No significant difference was found between the M2, M4 and AB groups ($P>0.05$). When 1 g/kg MOS was added to the diet, it significantly increased the digestibility of calcium (by 8.4%) and of phosphorus (by 7.4%) ($P\leq0.05$), but the further increase of the MOS dosage was associated with no further improvement in this case either. The treatments had no effect on the digestibility of fat and N-free extract.

The effect of various treatments on the apparent ileal digestibility of essential amino acids is shown in Table 2.

Table 2: The effect of dietary MOS supplementation on the apparent ileal digestibility of different amino acids (%)

	T R E A T M E N T S *					
	M0	**M1**	**M2**	**M4**	**AB**	**RMSE**
	n = 6	n = 6	n = 6	n = 6	n = 6	
Lysine	74.1^{b}	74.5^{b}	79.3^{a}	76.1^{b}	79.5^{a}	1.7
Methionine	84.4^{c}	89.5^{a}	88.0^{ab}	86.9^{b}	82.8^{c}	1.4
Cystine	54.0^{c}	74.8^{a}	72.2^{a}	65.0^{b}	74.1^{a}	3.1
Met+Cys	72.7^{d}	83.8^{a}	81.9^{ab}	78.5^{c}	79.4^{bc}	2.0
Threonine	59.1^{c}	70.4^{ab}	71.4^{a}	66.6^{b}	68.2^{ab}	2.9

* M0: negative control without antibiotic or MOS; AB: antibiotic treatment with 0.2 g/kg Maxus-200 (40ppm avilamycin supplementation); M1: supplementation of 1 g/kg MOS; M2: supplementation of 2 g/kg MOS; M4: supplementation of 4 g/kg MOS

$^{a, b}$ $P \leq 0.05$; RMSE: Root mean square error

No differences were found for lysine among the M0, M1 and M4 groups ($P>0.05$). In contrast to these groups however, the addition of 2 g/kg MOS (M2) improved the digestibility of lysine at the same rate as the growth promoting antibiotic did. When MOS was added to the diet, the ileal digestibility of methionine improved in comparison to the negative (M0) and to the positive control (AB) ($P>0.05$). It is also noteworthy, that while the apparent digestibility of methionine was 89.5% in treatment M1, it was found to be 2.6% lower in treatment M4 ($P\leq0.05$). The ileal digestibility of cystine followed the same trend as the ileal digestibility of methionine. The apparent ileal digestibility of threonine was only 59.1% in the negative control group, and all treatments, including also the antibiotic and the MOS supplementation improved this figure by about 10% ($P>0.05$).

3.2. The effect of dietary mannan-oligosaccharide supplementation on the N balance of weaned pigs

According to the results of our studies the mannan-oligosaccharide supplementation of the diet did not influence the N balance of the trial animals. N intake and N excretion did not differ when it was expressed either in g per animal or based on the metabolic bodyweight. The results of the N balance study are shown in Table 3.

Table 3: The effect of dietary MOS supplementation on N retention of weaned piglets

	T R E A T M E N T S *					RMSE
	M0	**M1**	**M2**	**M4**	**AB**	
N-balance (g/kg^{0,75}/day)	n = 9	n = 10	n = 10	n = 10	n = 9	
N-intake	2.8	2.8	2.7	2.7	2.7	0.2
N excretion via faces	0.25	0.29	0.32	0.29	0.27	0.08
N excretion via urine	0.51	0.52	0.48	0.49	0.45	0.06
N excretion, total	0.77	0.80	0.80	0.77	0.71	0.12
N-balance	2.0	2.0	1.9	1.9	2.0	0.2
N-retention (%)						
N- retention in % of N intake	72	72	71	71	74	3
N-retention in % of absorbed N	79	79	80	79	82	2

* M0: negative control without antibiotic or MOS; AB: antibiotic treatment with 0.2 g/kg Maxus-200 (40ppm avilamycin supplementation); M1: supplementation of 1 g/kg MOS; M2: supplementation of 2 g/kg MOS; M4: supplementation of 4 g/kg MOS

[a, b] $P \leq 0.05$; RMSE: Root mean square error

3.3. The effect of dietary mannan-oligosaccharide supplementation on the immune status of weaned pigs

3.3.1. Non-specific cellular immune response

The non-specific immune response of the pigs was enhanced in all of the animals from the 1st to the 5th blood sampling. Over the first four weeks of the lymphocyte stimulation tests conducted with ConA, PHA and PWM mitogens no statistically verifiable difference was found between the treatments (Table 4). The LST values were the highest on week 5 of the trial in the group fed the diet with 1 g/kg MOS supplementation.

When the lymphocyte stimulation was performed with ConA mitogen a significant difference was found between the 1 g/kg MOS supplemented group and the negative control, and also between the 1 g/kg MOS supplemented group and the positive control animals fed the growth promoting antibiotic, whereas the values found for the negative and the positive control pigs did not differ ($P>0.05$). With the PHA mitogen stimulation the value found for the 1 g/kg MOS supplemented group was significantly higher than that of the animals fed 4 g/kg MOS ($P<0.05$). The LST using PWM mitogens induced the weakest response in the negative control group, and this differed significantly from the 1 g/kg MOS supplemented group.

3.3.2. Specific cellular and humoral immune response

In order to determine the specific cellular immune response the lymphocytes were stimulated with AyV in our studies (Table 5).

A significant difference ($P<0.05$) was found between the treatments on week 3. The response was the strongest in the 1 g/kg MOS group. It is also remarkable that on week 3 there was no significant difference between the results of the antibiotic fed control group and the non-immunized group. Later on, from week 4, the difference between the immunized groups was statistically not verifiable ($P>0.05$).

Table 4: The effect of MOS supplementation on the lymphocyte stimulation test by non-specific mitogens (Con A, PHA and PWM)

	Time (weeks)	T R E A T M E N T S* MOS (g/kg)					P-value**		
		M0	**M1**	**M2**	**M4**	**AB**	**RMSE**	**Tr**	**R**
		n = 9	n = 9	n = 10	n = 10	n = 10			
ConA	1	5,08	5,10	5,13	5,10	5,08	0,054	0,19	-
	4	5,21	5,21	5,20	5,20	5,17	0,122	0,96	-
	5	$5,21^{b}$	$5,37^{a}$	$5,27^{ab}$	$5,24^{ab}$	$5,20^{b}$	0,105	0,02	0,001
PHA	1	3,73	3,72	3,76	3,69	3,71	0,071	0,45	-
	4	3,81	3,86	3,81	3,78	3,80	0,146	0,84	-
	5	$3,81^{ab}$	$3,98^{a}$	$3,86^{ab}$	$3,78^{b}$	$3,86^{ab}$	0,134	0,02	0,01
PWM	1	2,89	2,91	2,90	2,90	2,90	0,070	0,96	0,005
	4	3,06	3,17	3,09	3,12	3,07	0,125	0,34	-
	5	$3,06^{a}$	$3,27^{b}$	$3,18^{ab}$	$3,13^{ab}$	$3,10^{ab}$	0,148	0,048	-

* M0: negative control without antibiotic or MOS; AB: antibiotic treatment with 0.2 g/kg Maxus-200 (40ppm avilamycin supplementation); M1: supplementation of 1 g/kg MOS; M2: supplementation of 2 g/kg MOS; M4: supplementation of 4 g/kg MOS , NI: non immunized group fed with M0

** there was no interaction effect

a, b $P \leq 0.05$; RMSE: Root mean square error

Table 5: Effect of MOS supplementation on the specific cellular immune (Aujeszky's disease virus cell stimulationindex)

Time (Weeks)	T R E A T M E N T S*							P-value**	
	MOS (g/kg)						RMSE	Tr	R
	M0	M1	M2	M4	AB	NI			
	n = 9	n = 9	n = 10	n = 10	n = 10	n = 10			
1	0.88	1.01	1.01	1.00	1.01	1.01	0.13	0.56	0.22
2	1.28	1.34	1.24	1.28	1.19	1.02	0.27	0.10	0.04
3	1.57^{ab}	1.95^{a}	1.55^{ab}	1.56^{ab}	1.40^{bc}	1.04^{c}	0.33	0.0001	0.008
4	2.62^{a}	2.82^{a}	2.61^{a}	2.50^{a}	2.53^{a}	1.03^{b}	0.73	0.0001	0.0005
5	2.94^{a}	3.15^{a}	3.23^{a}	3.11^{a}	2.78^{a}	1.04^{b}	0.68	0.0001	0.85

* M0: negative control without antibiotic or MOS; AB: antibiotic treatment with 0.2 g/kg Maxus-200 (40ppm avilamycin supplementation); M1: supplementation of 1 g/kg MOS; M2: supplementation of 2 g/kg MOS; M4: supplementation of 4 g/kg MOS , NI: non immunized group fed with M0

** there was no interaction effect

$^{a, b}$ $P \leq 0.05$; RMSE: Root mean square error

In the VN test conducted to determine the specific humoral immune response the difference between the treatments was found to be significant already on week two following immunization (Table 6). The level of the specific antibody remained 0 in the non-immunized group, and compared to that the results of all groups differed significantly, except for the antibiotic supplemented animals. The level of antibody measured for the antibiotic supplemented group and the MOS supplemented groups did not differ statistically. Corresponding to the results of the specific LST, the VN test on week 3 showed a 1.8 times higher value for the 1 g/kg MOS group when compared to the other groups ($P<0.05$). From week 4 onwards the result of the negative control group was the lowest, although the difference between the groups was not statistically verifiable anymore ($P>0.05$).

The specific humoral local immune response of the pigs was determined after a controlled TGEV challenge by measuring the specific secretory (s)IgA level in the small intestine of the animals. The data from the first replicate were excluded from the statistical analysis due to technical reasons. The results are shown in Figure 2. Similarly to the other tested immune parameters the level of the TGEV specific (s)IgA was again the highest in the 1 g/kg MOS supplemented pigs, but the immunized groups only tended to differ from each other ($P=0.07$). In our study the (s)IgA concentration in the small intestine was measured to be the highest for the 1 g/kg MOS group and the lowest for the antibiotic treatment.

Table 6: The effects of MOS supplementation on humoral immune response (virus neutralization test, serum Aujeszky's disease virus neutralization titer, log2)

Time (weeks)	T R E A T M E N T S *						P-VALUE**	
	MOS (g/kg)							
	M0	**M1**	**M2**	**M4**	**AB**	**RMSE**	**Tr**	**R**
	n = 9	n = 9	n = 10	n = 10	n = 10			
1	0	0	0	0	0	-	-	-
2	0.88	1.50	1.11	1.11	0.70	0.721	0.22	-
3	1.88[b]	3.37[a]	1.66[b]	2.22[b]	1.90[b]	0.825	0.001	-
4	3.66	5.25	3.88	4.77	3.90	1.71	0.06	0.0001
5	4.77	5.87	5.33	5.66	4.70	1.12	0.12	-

[*] M0: negative control without antibiotic or MOS; AB: antibiotic treatment with 0.2 g/kg Maxus-200 (40ppm avilamycin supplementation); M1: supplementation of 1 g/kg MOS; M2: supplementation of 2 g/kg MOS; M4: supplementation of 4 g/kg MOS , NI: non immunized group fed with M0

** there was no interaction effect

[a, b] $P \leq 0.05$; RMSE: Root mean square error

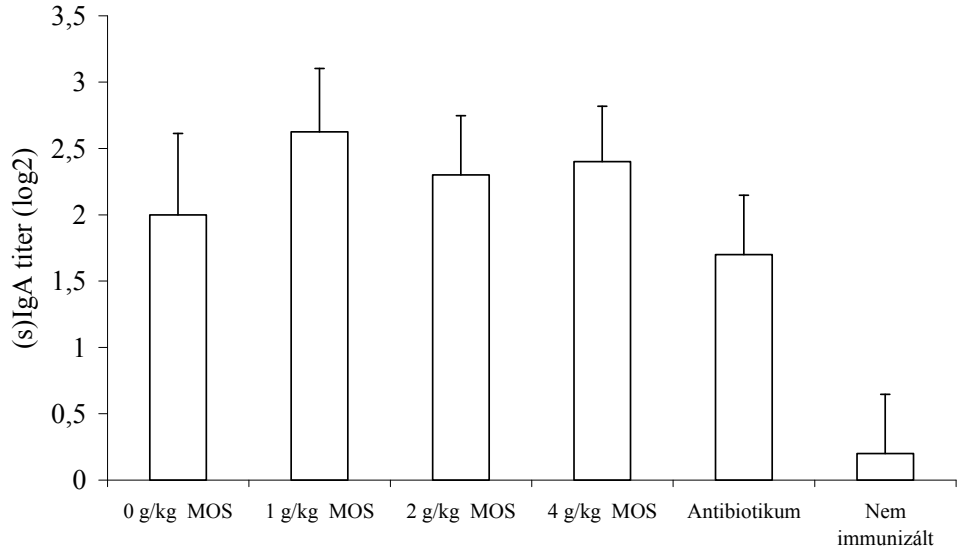

Figure 2: The effect of MOS supplementation on the local TGEV specific (s)IgA in the small intestine. Error bars indicated standard deviation and letters indicate differences at $P<0.05$

3.4. The effect of dietary mannan-oligosaccharide supplementation on the growth performance of weaned pigs

Bearing in mind the results of the digestibility studies we chose and fed only one MOS dosage (2 g/kg) in the performance study. The effect of the MOS supplementation added to pig diets on the growth performance of weaned pigs is shown in Table 7. Similarly to the N retention study no statistically verifiable differences were found between the treatments in this trial either. The average daily weight gain of the pigs was 221 g in the first phase (days 0 – 15) and 376 g in the second phase (days 15 – 31), which correspond to the actual farm results of the genetic potential. The total feed consumption in the average of pens was 81 kg and 170 kg for each phase. The average gain per pen was found to be 63 kg and 112 for the same phases. Accordingly, the feed conversion rate was 1.33 and 1.52 kg/kg on average for all groups.

Table 7: The effect of dietary MOS supplementation on growth performance of weaned piglets

	T R E A T M E N T S*			
	M0	**AB**	**M2**	**RMSE**
Initial body weight (kg)[1]	7.9	7.9	7.9	1.6
Average daily gain (g/day) [1]				
Phase 1 (day 0-15)	230	227	207	91
Phase 2 (day 15-31)	373	387	368	121
Overall (day 0-31)	304	309	289	87
Average daily feed intake (g/d) [2]				
Phase 1 (day 0-15)	304	306	299	26
Phase 2 (day 15-31)	640	673	590	94
Overall (day 0-31)	472	489	445	48
Feed conversion ratio (kg/kg) [2]				
Phase 1 (day 0-15)	1.24	1.25	1.49	0.26
Phase 2 (day 15-31)	1.54	1.53	1.49	0.28
Overall (day 0-31)	1.41	1.43	1.48	0.19

[*] M0: negative control without antibiotic or MOS; AB: antibiotic treatment with 0.2 g/kg Maxus-200 (40ppm avilamycin supplementation); M2: supplementation of 2 g/kg MOS; [a, b] $P \leq 0.05$; RMSE: Root mean square error

4. CONCLUSIONS AND RECOMMENDATIONS

1. The MOS supplementation of the diet is of key importance in the improvement of ileal digestibility of dry matter, crude protein, tested amino acids and Ca and P. The apparent ileal digestibility of methionine, cystine, methionine + cystine and threonine, and also of Ca and P improved above 5 %unit as a result of adding 1 g/kg MOS to the diet, but the higher dosage led to no further improvement of the digestibility. As for protein and lysine, the addition of 2 g/kg MOS was associated with the same level of improvement in digestibility (5%unit) as was achieved with the growth promoting antibiotic compared to the negative control ($P>0.05$). The effect of supplementing the diet with 4 g/kg MOS on the apparent ileal digestibility of dry matter, lysine, and Ca and P did not differ from that of the group without MOS ($P>0.05$).
2. The results of the immunology studies consistently indicate that supplementing the diet with MOS has a dose-dependent positive impact on the specific and non-specific immune response of pigs weaned at the age of day 28.
3. In the lymphocyte stimulation tests conducted to determine the non-specific cellular immunity (ConA, PHA, PWM) the immune response was found to be the strongest in the group fed the diet with 1 g/kg MOS supplementation. The difference among dietary treatments was verifiable on week 5 ($P<0.05$; ConA: 0 vs. 1 g/kg MOS and growth promoting antibiotic vs. 1 g/kg MOS; PHA: 4 vs. 1 g/kg MOS; PWM: 0 vs. 1 g/kg MOS).
4. In the study of specific cellular immune response the lymphocyte stimulation ability was found to be the strongest in the 1 g/kg MOS

supplemented groups over the entire trial period, but the differences among the treatments were statistically verifiable on week 3 only ($P<0.05$; growth promoting antibiotic vs. 1 g/kg MOS). On week 3 the specific cellular immune response of the antibiotic supplemented group was the same as the LST measured for non-immunized pigs ($P>0.05$).

5. The specific humoral immune response was the strongest in the 1 g/kg MOS supplemented group; the Aujeszky virus neutralization ability was statistically different from the other treatments 2 weeks following immunization ($P<0.05$).
6. The local specific immune response (the level of local TGE specific (s)IgA measurable in the small intestine) was the highest in the group fed the 1 g/kg MOS supplementation ($P=0.07$; growth promoting antibiotic vs. 1 g/kg MOS).
7. In pigs kept under good sanitary and housing conditions the MOS supplementation of the diet improves the immune response of the animals without an adverse effect on the N retention or the growth performance.

Recommendations:

1. It can be concluded from our results that from the aspect of improving the apparent ileal digestibility of nutrients the optimum level of MOS supplementation is 1-2 g/kg, whereas the optimum level for boosting the immune response of the animals is 1 g/kg MOS supplementation. Adding MOS to the diet at concentrations in excess of 2 g/kg is not recommended because it will not improve or may even impair the digestibility of nutrients and the immune response of the animals.

2. Our results suggest that it may be useful to set up an on-farm study feeding a 1 g/kg MOS dosage to animals of average or poorer than average health status.

3. The further study of the efficacy and mode of action of MOS supplementation is needed for the successful application of the product.

5. NEW SCIENTIFIC ACHIEVEMENTS

1. MOS supplementation in lower dosages (1-2 g/kg) improves the tested parameters, while the higher dosage (4 g/kg) does not influence, or in some cases even impairs them in the case of 28 days old weaned piglets. When 1 g/kg MOS is fed there is a statistically verifiable improvement in the apparent ileal digestibility of methionine, cystine and threonine and of Ca and P; supplementing the diet with 2 g/kg MOS is associated with the statistically verifiable improvement of the dry matter, crude protein and lysine.

2. The specific humoral and cellular immune response of weaned pigs becomes stronger as early as 2 weeks after the immunization when their diet is supplemented with 1 g/kg of MOS, but when the higher dosage is fed this improvement does not occur.

3. In pigs kept under good sanitary and housing conditions the MOS supplementation of the diet improves the immune response of the animals without an adverse effect on the N retention or the growth performance.

6. PUBLICATIONS AND PRESENTATIONS

6.1. Papers published in peer-reviewed journal in foreign language

1. Nochta, I., Tuboly, T., Halas V, Babinszky L. (2009) The effect of different levels of dietary mannan-oligosaccharide on specific cellular and humoral immune response in weaned piglets. *Journal of Animal Physiology and Animal Nutrition*, 93 (4): 496-504.
2. Nochta, I., Halas, V., Tossenberger, J., Babinszky, L. (2010) Effect of different levels of mannan oligosacharid supplementation on the apparent ileal digestibility of nutrients, N-balance and growth performance of weaned piglets. *Journal of Animal Physiology and Animal Nutrition* (in press). http://www3.interscience.wiley.com/journal/123226821/abstract

6.2. Abstract published in peer-reviewed journal

Nochta I, Tuboly T, Halas V, Babinszky L (2007) The effect of different levels of dietary mannanoligosaccharide on specific cellular and humoral immune response in weaned piglets. *Journal of Animal Science* 85: 149.

6.3. Paper published in peer-reviewed journal in Hungarian

Nochta Imre, Halas Veronika és Babinszky László (2009) Élesztősejtfal eredetű mannan-oligoszacharidok felhasználása a sertéstakarmányozásban. *Magyar Állatorvosok Lapja* 131: 532-542

6.4. Technical papers

1. Dr. Nochta I.(2000) Egészséges malacnevelés. *Híd* 2000/1. 10.
2. Dr. Nochta I.(2002) Prebiotikumok a sertéstakarmányozásban. *Híd* 2002/1: 5.
3. Dr. Nochta I. (2002) Hozamfokozás antibiotikumok nélkül. *Híd* 2002/4: 9.
4. Dr. Nochta I. (2003) Sikeres malacnevelés. *Agrárágazat* 2003. augusztus, 43-44.
5. Dr. Nochta I. (2003) Gyakorlati tapasztalatok új malactápjainkkal. *Agronapló* 76: 51.
6. Nochta I. és Babinszky L. (2004) Oligoszacharidok a monogasztrikus állatok takarmámyozásában. *Takarmányozás* 7(1): 5-8.
7. Dr. Nochta I. (2004) A bélflóra stabilitása és az immun folyamatok alakulása malacokban. *Híd* 2004/3: 10.
8. Dr. Nochta I. (2004) Immunstimuláció? *Híd* 2004/3: 7.

6.5. Oral presentations

1. Dr Nochta I.: Az antibiotikum típusú hozamfokozók helyettesítésének lehetőségei; Magyar Állatorvos Kongresszus Budapest 2002. október
2. Dr. Nochta I.: Prebiotikumok a sertéstakarmányozásban; Magyar – Holland projekt, Pécs, 2004. 03. 02.
3. Dr. Nochta I.: Egy jó választás…; Sertés takarmányozási szimpozium. Pálmajor 2004. 06.17.
4. Dr. Nochta I.: Mannan oligosaccharides in weaner feed; Provimi Swine Training Barcelona 2005.09.
5. Dr. Nochta I.: A takarmányok oligoszacharid kiegészítésének hatása a táplálóanyagok emészthetőségére, valamint a bél mikroflóra és az

immunstátusz változására választott malacokban, Mosonmagyaróvár, 2008. 08.

6. Dr. Nochta I.: The effect of different level of dietary mannan-oligosaccharide on specific cellular and humoral immun response in weaned piglets ADSA/PSA/ AMPA/ASAS Joint Annual Meeting San Antonio, Texas, USA, 2007.07.
7. Dr. Nochta I.: A malacok választás előtti és választás utáni takarmányozása Állatorvosok Sertésegészségügyi Tártsasága Kongresszusa, Budapest, 2009.09.30.
8. Dr. Nocha I.: Malacnevelés hatékonyan! TOPIGS szimpozium, Kölesd. 2010. 01.