

## PREBIOTICS IN NUTRITION OF SOWS AND PIGLETS

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Invited paper

**Abstract:** The effects of prebiotic Bio Mos (0.2%) used in nutrition of gestating and sows in lactation, as well as Bio Mos (0.5%) and fructo-oligosaccharides (0.4%) used in nutrition of suckling piglets were investigated. Obtained results showed that the introduction of additives in mixtures influenced: greater food intake of sows in lactation by 13.75 %, by 14.7% more born piglets and by 3.6% heavier piglets at birth, greater litter weight by 3.1 % at weaning and better intake of pre-starter by 6.7% per litter during lactation. In general, obtained results showed that the use of investigated prebiotic Bio Mos and fructo-oligosaccharides are recommended for use in nutrition of sows and suckling piglets.

**Key words:** prebiotics, sows, suckling piglets

### Introduction

Disease has always been a critical issue in pig production, affecting not only animal health and well-being, but also the physical and economic health of the producer. Growth promoting antibiotics have been fed to livestock since the 1940's and have generally enhanced pig performance (*Cromwell, 2000*). Growth promoting antibiotics act by a variety of mechanisms to alter the intestinal microbiota, with subsequent direct and indirect effects on the pig (*Anderson et al., 2000, Gaskins et al., 2000*). Enteric disease issues are coming to the forefront as governmental and public concerns about pre-harvest food safety and microbial antibiotic resistance increase. The European Union is phasing out use of growth promoting antibiotics and there is increasing pressure to do so in North America. Thus, there is increasing interest in alternatives to growth promoting antibiotics. Fundamental to developing alternatives to growth promoting antibiotics is the enhancement of our understanding of defence systems used to inhibit pathogens, their interactions and regulation. The pig's defence against pathogens includes a combination of physical processes (gastric acidification, rapid transit through the small intestine), as well as the epithelial lining of the intestine, the mucosal

immune system and the intestinal microbiota (*Gaskins et al., 2000; Mackie et al., 1999*). Effective defence against pathogens requires that all of these systems are functioning properly.

In feed antimicrobials have been widely used within the swine industry to prevent disease and promote growth rate and feed efficiency. The use of in-feed antimicrobials has long been recognized as an effective management practice to improve pig performance (*Hays, 1978; Zimmerman, 1985*). High requirements imposed on pork producers in the field of the quality of meat are favourable for the intensification of studies on feed additives, in particular substitutes of feed antibiotics (*Kjeldsen, 2002*). The effectiveness of the alternative application of Antibiotics, bio stimulators, among others from the group of probiotics, prebiotics and symbiotics is not, however, univocal (*Kornegay and Risley, 1996; Houdijk et al., 1998; Harper and Estinne, 2002*).

The quantity and proportions of micro-organisms living in alimentary tract are relatively constant and typical of the particular periods of life of individual. They are subject to changes, depending on the consumed feeds, *inter alia*, on feed additives, in the state of health as well as during disease and stress situation (*Stavric and Kornegay, 1995*).

Prebiotics are defined as “a nondigestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon” (*Gibson and Roberfroid, 1995; Biaggi, 2007*). Fructooligosaccharides (FOS), galactooligosaccharides (GAL) and mannanoligosaccharides (MOS) have been the most widely studied oligosaccharides as the alternatives to antimicrobials in swine diets (*Flickinger et al., 2003*). Fructooligosaccharides (FOS) and mannanoligosaccharides (MOS) have been the most widely studied oligosaccharides as alternatives to antimicrobials in swine diets.

Taking into consideration our previous studies which indicated positive effects of prebiotics used in nutrition of gilts (*Živković et al., 2005*), sows and piglets (*Živković et al., 2003, 2006a,b*), piglets in rearing (*Živković et al., 2001; Grčak et al., 2002; Stanković et al., 2003*) as well as pigs in fattening (*Živković et al., 2004, 2006a; Živković and Stanojlović, 2006*), objective of this paper was to investigate the possibilities for use of prebiotics Bio Mos and Fructooligosaccharides, in nutrition of gestating and sows in lactation, as well as suckling piglets.

## Materials and Methods

Studies were realized on private farm in the vicinity of Šabac. Trial included total of 18 sows distributed in two nutrition treatments. Thirty days before farrowing gestating sows were successively included in the trial, sows

were kept in group boxes 10 days before farrowing, and fed daily diet of 3,0 kg/animal (Table 1).

**Table 1. Scheme of the experiment**

Group	1 control	2 experimental
Gestating sows		
Bio Mos 30 days before the farrowing, % in the diet	-	0.2
Lactating sows		
Bio Mos during the lactating period, % in the diet	-	0.2
Suckling piglets		
Bio Mos just after the farrowing, oral application, ml/head	-	10
Bio Mos in the creep feeding, % in the diet	-	0.3
Sel Plex in the feed, % in the diet	-	0.015
The mixture of fructo-oligosaccharides, plant extracts, organic acids, % in the diet	-	0.4

First group was fed mixture of standard composition and without added prebiotic. Sows of the second group – trial group, were fed diet of same composition to which 0.2 % of studied prebiotic Bio Mos was added.

Bio-Mos, a mannan oligosaccharide product manufactured by Alltech, Inc (Nicholasville, Kentucky), is believed to positively influence performance of nursery pigs. This product, derived from the cell wall of yeast (*Saccharomyces cerevisiae*), consists of a mannan and a glucan component. The structure of the mannan component resembles that of the surface glycoproteins containing mannose present on the mucosal surface of the intestine. The mannans act as high-affinity ligands for the mannose-specific type-1 fimbriae of pathogenic bacteria such as *Escherichia coli* 6 and salmonellae (Spring *et al.*, 2000).

Ten days prior to farrowing, all sows in gestation were moved to nursery. Sows of first, control, group and second group were fed diets for lactating sows, and the use of studied prebiotic continued in the second group in the same concentration like in the previous period. During lactation, sows in both groups were fed ad libitum.

Immediately after farrowing, piglets of the trial group received orally 10 ml/animal of Bio Mos, and starting from 10 days of age they were creep fed using mixtures for creep feeding, where again control group received food without additive and piglets from sows of the second group received in diet combination of 0.4% of Bio Mos, 0.015% Sel Plex and 0.4% fructooligosaccharides, plant extracts and organic acids in the mixture.

Criteria for assessment of obtained results were following: sow food intake month before farrowing and during lactation, number of born piglets, number of weaned piglets, average weight of piglets at birth and weaning, average litter

weight, average daily gain of piglets during lactation and intake of food of piglets during lactation.

Statistical processing of data relating to intake of food by lactating sows, weight of piglets at birth and weaning, gain and intake of food used in creep feeding of piglets was realized by conventional statistical method, variance analysis, and data relating to average values by t-test.

## Results and Discussion

**a) Period of gestation and lactation.** The possibility of introduction of prebiotic Bio Mos into nutrition of gestating and sows in lactation, as well as suckling piglets was studied in the trial. Obtained results (table 2) show that sows in control group fed diet without added prebiotic, consumed 5.09 kg/animal of food. Introduction of Bio Mos to the diet during lactation lead to increase in food intake, in average by 0.70 kg or 13.75% ( $P<0.05$ ) compared to control mixture.

**Table 2. Performance of sows in the experiment**

Group	1 control	2 experimental
Technology of Alltech's production, last 30 days of gestation	-	+
Gestating sows		
Feed/head/day, kg	3.0	3.0
Lactating sows		
Technology of Alltech's production during lactation	-	+
Average daily feed intake, kg	5.09 <sup>a*</sup>	5.79 <sup>a</sup>
Compared to the control group, %	-	+ 13.75

*\*) – The same letter over the average values designate the statistical difference on the level  $P<0.05$ .*

In regard to number of live born piglets, in trial group with 12.75 live born piglets per litter, in average by 1.63 piglets or 14.66% ( $P<0.05$ ) more piglets was born compared to control group of sows. Body weight of piglets at birth in group with Bio Mos in nutrition was higher by 0.05 kg or 3.62% compared to animals from control group.

At the end of lactation, use of Alltech technology resulted in more weaned piglets in litter by average 0.50 animals or 5.07% compared to first, control, group fed diet without the additive. Lower body weight of piglets from the trial group at weaning, in average by 0.33 kg or 3.63%, and slightly lower gain by 7 g or 3.24% is practically compensated by greater weight of litter at weaning by average 2.70 kg or 3.09 % compared to parameters established in control group of piglets.

**Table 3. Performance of suckling piglets in the experiment**

Group	1 control	2 experimental
Technology of Alltech's production during lactation	-	+
Suckling piglets		
Number of liveborn equalized piglets/litter*	11.12 <sup>a**</sup>	12.75 <sup>a</sup>
Number of stillborn piglets/litter	0.0	0.87
Number of weaned piglets/litter	9.87	10.37
Average body weight of the piglets at farrowing, kg	1.38	1.43
Compared to the control group, %	-	+ 3.62
Average body weight of the piglets at weaning, kg	9.08	8.75
Compared to the control group, %	-	- 3.63
Average body weight of the litter at weaning, kg	87.4	90.1
Compared to the control group, %	-	+ 3.09
Average daily gain of piglets, g	216	209
Predstarter/litter during creep feeding, kg	11.06 <sup>A</sup>	11.80 <sup>A</sup>
Compared to the control group, %	-	+ 6.69

\*) – Uniformity of piglets in the litters includes transfer of the piglets from litter to litter within the group after all the colostrum has been suckled

\*\*\*) – The same small letter over the average values designate the statistical difference on the level  $P < 0.05$ , and the big ones on the level  $P < 0.01$

Introduction of Alltech additives into mixture used for creep feeding of piglets enabled better intake of ore-starter, in average by 0.74 kg or 6.69% ( $P < 0.01$ ) compared to control group of piglets.

It was confirmed that by use of studied Alltech's additives better production in sows and suckling piglets is realized.

The most common commercial source of MOS is yeast because MOS comprise approximately 45% of the cell wall of *S. cerevisiae* (Tizard *et al.*, 1989). Thus, many of the inconsistencies in the responses of pigs fed yeast are also prevalent in studies in which pigs were fed MOS. Yeast reduced colonization of total coliforms in the duodenum, jejunum, cecum, and colon, but it did not have a consistent effect on colonization of *E. coli* (White *et al.*, 2002). Great potential in prevention of the diarrhoea syndrome of piglets and subsequent improvement in animal growth and feed conversion has been attributed to organic acids, probiotics or/and prebiotics. Although some studies do show little response, a number of studies have shown at least trends for improvements in growth performance, decrease in variation, mortality and morbidity, or decreased medicine costs when prebiotics are fed (Patterson and Burkholder, 2003).

Several antimicrobial alternatives have been extensively researched. Results for mannan- oligosaccharides have been conflicting, with some studies showing improvements in growth performance (Dvorak and Jacques, 1998; Hancock *et al.*, 2002). To compare the effects of several antimicrobial alternatives and in-feed antimicrobials on nursery pig performance. Use of Bio Mos influenced

the increase of daily gain in suckling piglets from 317 g to 321 grams, i.e. improvement of 1,26% compared to control group of animals fed diet without additive in mixture (Keegan et al., 2005). A review of 49 comparisons of performance with use of a mannan oligosaccharide found increases of 4.18%, 2.14%, and 2.24% for daily gain, feed intake and feed efficiency, respectively (Miguel et al., 2002).

Harper and Estienne (2003) found several factors may contribute to the lack of response to antimicrobial alternatives. The first is the purity and degree of specificity of the organisms used in the antimicrobial alternative products. The number of strains of bacteria used in such feed additives and the condition of the cultures in which they are produced may affect consistency of piglets' growth performance. Because many antimicrobial alternatives contain live cell cultures, effectiveness depends on proper storage of the products and longevity of the cultures. All products used in these trials were evaluated within the recommended product-stability timelines provided. All products used in these trials were evaluated within the recommended product-stability timelines provided by the manufacturers and were stored to meet manufacturer recommendations. A summary of 10 trials conducted with the use of antimicrobials in nursery pigs reported a smaller increase in pig performance with the use of in feed antimicrobials. It is suggested that use of infeed, growth promoting antimicrobials in multi-site pig production should be limited to therapeutic applications in pigs (Dritz et al., 2002).

In a comparison with both control and prebiotic treatments, pigs fed the prebiotic treatments had an 8.9% increase in ADG and a 1.6% increase in G/F. In all of these comparisons, performance response was greater when ADG of the controls was closer to 0.3 than to 0.4 kg/d. This data suggests that when comparing efficacy of prebiotics, it is important to include a growth promoting antibiotic treatment as a positive control and that the growth rate of the control animals should be a good indicator of whether one should see a growth promoting response with any treatment (Patterson, 2005). Mannan oligosaccharides (MOS) have been shown in a number of livestock species to provide benefits similar to antibiotic growth promoters (Dvorak and Jacques, 1998; Newman, 2001). In pigs, MOS supplementation has resulted in better gains, feed conversion, enhanced lymphocyte transformation and immunoglobulin concentrations than in unsupplemented animals (Miguel et al., 2002; Spring and Pirvulescu, 1998). The most common commercial source of MOS are the yeasts, because MOS comprise approximately 45% of the cell wall of *S. cerevisiae* (Tizard et al., 1989).

In suckling piglets, Manan-oligosaccharides supplementation has improved feed conversion and enhanced lymphocyte transformation and immunoglobulin concentrations than in non-supplemented piglets' diets (Miguel et al., 2002; Newman, 2006).

The Mannan-oligosaccharides or Fructo-oligosaccharides supplement may be beneficial in piglet rearing as it reduces the piglet losses in the whole rearing period (from birth to 84 days) from 12.24% in the control group (without AGP) to 6.32% in the group fed the mixture supplemented with MOS and to 8.25% with FOS. These additives induced advantageous performance traits and lowered the level of total cholesterol and LDL-cholesterol (*Grela et al., 2006*). *Pettigrew (2000)* reviewed 17 studies in which weaning pigs were fed MOS and reported that 14 of the studies showed numerical, although small, advantages in growth, feed intake, and feed efficiency. However, the overall response of improved growth rate was 4.4%, which is smaller than the 16% average increase in growth when antibiotics were fed. *Miguel et al. (2002)* and *Pettigrew (2000)* concluded that there was not enough evidence to suggest a beneficial effect on growth performance of finishing pigs fed MOS.

Antibiotics improve health and productive performance of pigs. There is increasing evidence that other dietary ingredients may provide similar, but probably not identical, benefits. Colostrum quality, as defined by immunoglobulin (Ig) content, has been shown to be enhanced when Bio-Mos® is included in gestation diets of sows diets beginning 14 days pre-farrowing (*O'Quinn et al., 2001; Newman and Newman, 2001*).

Mannan oligosaccharides preparation added to feed stimulates antioxidant reactions both in experimental sows and in their piglets. Used indicators of the antioxidant system especially superoxide dismutase (SOD), blood plasma activities of catalase (CAT), and ferric ability reducing of plasma (FRAP), are very sensitive exponents of antioxidant status of swine. Species of grain (wheat or triticale) did not have any significant influence on the analysed sows' and piglets' blood parameters. Probably, the administration of Bio-Mos preparation to sows during pregnancy had higher influence on antioxidant protection in newly born piglets than in sows. Mannan oligosaccharides supplementation increased plasma iron content, both in sows and in piglets (*Czech et al., 2009*).

Interesting seems to be also the observed in both experiments the correlation between administration of MOS and increased HDL fraction of cholesterol and lowering LDL cholesterol fraction (*Grela et al., 2006*). Mannan oligosaccharide supplementation increases serum levels of IgM and tends to increase colostral IgG levels in sows (*Newman, 2001; Newman, 2006*).

#### **Effects mannan oligosaccharides on gut health and immune function.**

The influence of dietary MOS on gut health and immune function in swine is not as well defined. Trials indicated that dietary inclusion of MOS enhanced immunoglobulin levels in both germfree and conventionally reared (CR) pigs. Furthermore, there was a significant increase in the number of Blymphocytes present in the small intestine of pigs fed MOS. In vitro, the proliferation of intestinal lymphocytes and phagocytosis of *Staphylococcus aureus* by macrophages were enhanced in germ-free and CR pigs fed MOS. This result might have been

caused by increased levels of the cytokines IL-2 and IFN $\gamma$  observed in MOS supplemented pigs (*Spring and Pirvulescu, 1998*). *Kim et al. (2000)* observed that pigs fed diets containing MOS had lower CD4 $^{+}$  (helper) T-cell and higher CD8 $^{+}$  (killer) T-cell counts than pigs not fed MOS. As a whole, these studies in swine suggest that dietary MOS is capable of inhibiting colonization of the gut by certain pathogens; however, the mechanism by which dietary MOS influences the immune system of pigs is not well defined.

Dietary supplementation of oligosaccharides enhanced growth performance by increasing apparent digestibility, decreasing the incidence of diarrhoea, and improving small intestinal. Fructooligosaccharides is a group of oligosaccharides, commonly used as a prebiotic dietary supplement. The combination maltodextrins and fructooligosaccharides proved the most effective one to inhibit the content of *E. coli* adhering to the intestinal mucosa of the jejunum and colon of piglets (*Nemcová et al., 2007*). The supplementation of oligofructose to an antibiotic-free creep feed during pre-weaning period affected gut microbial population (*Shim et al., 2005*).

## Conclusion

Effects of the use of prebiotics Bio Mos in the nutrition (0.2%) of gestating and lactating sows, and suckling piglets (Bio Mos 0.5%, and mix additives – 0.4%) were investigated. Obtained results showed that: introduction of used additives in the diets had an effect which was characterized by:

- greater food intake in lactating sows by 13.75 %,
- more born piglets by 14.7% and heavier by 3.6% at birth,
- greater body weight of litter by 3.1 % at weaning,
- better intake of pre-starter by 6.7% per litter during lactation.

In general, obtained results indicated that the use of studied prebiotics Bio Mos and fructooligosaccharides in nutrition of sows and suckling piglets can be recommended.

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## Prebiotici u ishrani krmača i prasadi

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### Rezime

Ispitivani su efekti korišćenja prebiotika Bio Mos (0,2%) u ishrani suprasnih i krmača u laktaciji kao i Bio Mosa (0,5%) i fruktooligosaharida (0,4%) kod prasadi na sisi. Dobijeni rezultati su pokazali da ee uvođenje korišćenih aditiva u smešama imalo efekte izražene:

- većom konzumacijom hrane krmača u laktaciji, za 13,75%,
- većim brojem, za 14,7%, oprasene i za 3,6% teže, prasadi na prašenju,
- većom telesnom masom legla za 3,1% na zalučenju,
- boljom potrošnjom predstartera za 6,7% po leglu tokom laktacije

U celini dobijeni rezultati su pokazali da se preporučuje korišćenje ispitivanih prebiotika Bio Mosa i fruktooligosaharida u ishrani krmača i prasadi na sisi.

### References

- ANDERSEN D.B., McCracken V.J., AMINOV R.I., SIMPSON J.M., MACKIE R.I., VERSTEGEN M.W.A., GASKINS H.P. (2000): Gut microbiology and growth-promoting antibiotics. *Pig News and Information*, 20, 1115-1122.
- BIAGI G. (2007): Dietary non-pharmacological alternatives to the use of antibiotics as growth promoters in swine. *Biotechnology in Animal Husbandry*, 23, 5-6, 77-85.
- CZECH A., MOKRZYCKA A., GRELA E.R., PEJSAK Z. (2009): Influence of mannanoligosaccharides additive to sows diets on blood parameters of sows and their piglets. *Bulletin Vet. Inst. Pulawy*, 53, 89-95.
- CROMWELL G.L. (2000): Why and how antibiotics are used in swine production. In: *Proceedings of the Pork Industry Conference on Addressing Issues of Antibiotic Use in Livestock Production*. Ed. L.B. Schook. Univ. Illinois, Urbana, 7-27.
- DRITZ S.S., TOKACH M.D., GOODBAND R.D., NELSSSEN J.L. (2002): Effects of aministration of antimicrobials in feed on growth rate and feed efficiency of pigs in multisite production systems. *JAVMA*, 220, 1690-1695.
- DVORAK R.A., JACQUES K.A. (1998): Mannanoligosaccharide, fructooligosaccharide and Carbadox for pigs days 0-21 post-weaning. *J. Anim. Sci.*, 76, Suppl. 2, 64 (Abs.).

- FLICKINGER E.A., van LOO J.J., FAHLEY G.C.Jr. (2003): Nutritional responses to the presence of inulin and oligofructose in the diets of domesticated animals: a review. *Crit. Rev. Food Sci. Nutr.*, 43, 19-60.
- GASKINS R.H., COLLIER C.T., ANDERSON D.B. (2000): Antibiotics as growth promotings: mode of action. In: *Proceedings of the Pork Industry Conference on Addressing Issues of Antibiotic Use in Livestock Production*. Ed. L.B. Schook. Univ. Illinois, Urbana, 29-42.
- GIBSON G.R., ROBERFROID M.B. (1995): Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. *Journal Nutrition*, 125, 1401-1412.
- GRČAK D., RADOVANOVIĆ T., STOLIĆ N., MILENKOVIĆ M., MILOVAN G., ŽIVKOVIĆ B., PAUNOVIĆ M. (2002): Primena probiotika Paciflora C-10 u ishrani prasadi. *Agroznanje Nauka – Tehnologija – praksa IV-ta godina*, Teslić, Banja Luka, 1, 46-52.
- GRELA E.R., SEMENIUK V., CZECH A. (2006): Efficacy of fructooligosaccharides and mannanoligosaccharides in piglet diets. *Medycina Wet.*, 62, 7, 762-765.
- HANCOCK J.D., JONES C.L., STARKLEY C.W. (2002): Effects of mannanoligosaccharides in diets for nursery pigs. *Journal of Animal Science*, 80, suppl 2, 68, 148 (abstract).
- HARPER A., ESTIENNE M. (2003): Alternatives to antimicrobial growth promoters not as effective as traditional antimicrobial additives for nursery pig. *Livestock Update*, May. <http://www.ext.vt.edu/news/periodicals/livestock/asd-02-05/asp-100.html>
- HAYS V.W. (1978): Effectiveness of feed additive usage of antibacterial agents in swine and poultry production. Report to the Office of Technology Assessment. Washington, DC: US Government Printing Office.
- HARPER A.F., ESTIENNE M.J. (2002): Efficacy of three potential alternatives to antimicrobial feed additives for weanling pigs. *Prof Anim Sci.*, 18, 343-350.
- HOUDIJK J.G.M., BOSCH M.W., VERSTEGEN M.W.A., BERENPAS H.J. (1998): Effects of dietary oligosaccharides on the growth performance and faecal characteristics of young growing pigs. *Anim. Feed Sci. Technol.*, 71, 35-48.
- KEEGAN T.P., DRITZ S.S., NELSEN J.L., ROUCHEY De J.M., TOKACH M.D., GOODBRAND R.D. (2005): Effects of in-feed antimicrobial alternatives and antimicrobials on nursery pig performance and weight variation. *Journal Swine Health Production*, 13, 1, 12-18.
- KJELDSSEN N. (2002): Producing pork antibiotic growth promoters: the Danish experience. *Adv. Pork Prod.*, 13, 107-115.
- KIM J.D., HYUM Y., SOHN K.S., KIM T.J., WOO H.J., HAN I.K. (2000): Effects of mannanoligosaccharide and protein levels on growth performance and immune status in pigs weaned at 21 days of age. *Korean J. Anim. Sci.*, 42, 489.

- KORNEGAY E.T., RISLEY C.R. (1996): Nutrient digestibilities of a corn-soybean meal diet as influenced by *Bacillus* products fed to finishing swine. *J. Anim. Sci.*, 74, 799-805.
- MACKIE R.I., SGHIR A., GASKINS H.R. (1999): Developmental microbial ecology of the neonatal gastrointestinal tract. *American Journal Clinical Nutrition*, 69, 1035-1045.
- MIGUEL J.C., RODRIGUEZ-ZAS S.L., PETTIGREW J.E. (2002): Practical effects of Bio-Mos in nursery pig diets: a meta-analysis. In: Lyons TP, Jacques KA, eds. Proc Alltech's 18th Ann Symposium.
- MIGUEL J.C., RODRIGUEZ-ZAS S.L., PETTIGREW J.E. (2002): Practical response to Bio-Mos in nursery pigs: a meta-analysis. In: LYONS T.P., JACQUES K.A. (eds), *Nutritional biotechnology in the feed and food industries*. Proc. Alltech.s 16th Internat. Feed Industry Symp., Nottingham Press University, Nottingham, UK , 426-433.
- MIGUEL J.C., RODRIGUEZ-ZAS S.L., PETTIGREW J.E. (2004): Efficacy of a mannan oligosaccharide (Bio-Mos<sup>v</sup>) for improving nursery pig performance. *Journal of Swine Health and Production*, 296-307.
- NEMCOVÁ R., BOMBA A., GANCARCÍKOVÁ S., REIFFOVÁ K., GUBA P., KOSCOVÁ J., JONECOVÁ I. (2007): Effect of administration of lactobacilli, maltodextrins and fructooligosaccharides upon the adhesion of *E. coli* O8:K88 to the intestinal mucosa and organic acid levels in gut content of piglets. *Vet. Res. Comm.*, 31, 7, 791-800.
- NEWMAN K. (2001): Mannan oligosaccharides: natural polymers with significant impact on the gastrointestinal microflora and the immune system. In: LYONS T.P., JACQUES K.A. (eds): *Biotechnology in the feed industry*. Proc. Alltech.s 17th Annual Symp., Nottingham University Press, Nottingham, UK , 167-174.
- NEWMAN M. (2006): Effects of mannan oligosaccharide source and structure on antibiotic resistance of pathogenic bacteria. In: LYONS T.P., JACQUES K.A. (eds), *Biotechnology in the feed industry*. Proceedings of Alltech's 22nd Annual Symposium, Nottingham Press University, Nottingham, UK, 109-113.
- NEWMAN K.E., NEWMAN M.C. (2001): Evaluation of mannan oligosaccharides on the microflora and immunoglobulin status of sows and piglet performance. *J. Anim. Sci.*, 79, 189.
- O'QUINN P.R., FUNDERBURKE D.W., TIBBETTS G.W. (2001): Effects of dietary supplementation with mannan oligosaccharide on sow and litter performance in commercial production systems. *J. Anim. Sci.*, 79, 212.
- PATTERSON J.A., BURKHOLDER K.M. (2003): In: R.O. BALL (eds): *9th International Symposium of Digestive Physiology in Pigs*, University of Alberta. Edmonton, CA, 319-331.
- PATTERSON J.A. (2005): Prebiotic feed additives: Rationale and use in pigs. *Advances Pork Production*, 16, 149-159.

- PETTIGREW J. E. (2000): Bio-Mos effects on pig performance: a review. In: LYONS T.P., JACQUES K.A. (eds), *Biotechnology in the feed Industry. Proc. 16th Annual Symp.* (, eds), Nottingham University Press, UK, 31-34.
- SHIM S.B., VERSTEGEN M.V.A., KIM I.H., KWON O.S., VERDONK J.M.A.J. (2005): Effects of feeding with oligofructose, probiotics or synbiotics to suckling piglets increases the preweaning weight gain and composition of intestinal microbiota. *Archives of Animal Nutrition*, 59, 6, 419-427.
- SPRING P., PIRVULESU M. (1998): Mannan oligosaccharide: its logical role as a natural feed additive for piglets. In: LYONS T.P., JACQUES K.A. (eds), *Biotechnology in the feed industry. Proc. Alltech's 14<sup>th</sup> Annual Symp.* Nottingham Press University, Nottingham, UK, 553-561.
- SPRING P., WENK C., DAWSON K.A., NEWMAN K.E. (2000): The effects of dietary mannanoligosaccharides on cecal parameters and the concentrations of enteric bacteria in the ceca of *Salmonella*-challenged broiler chicks. *Poultry Sci.*, 79, 205-211.
- STANKOVIĆ B., RADOVIĆ Č., RADIVOJEVIĆ D., HRISTOV S., RELIĆ R., ŽIVKOVIĆ B., HEGEDIŠ J. (2003): Ispitivanje uticaja nekoliko probiotskih populacija u sprečavanju digestivnih poremećaja zalučene prasadi. Simpozijum: Veterinarstvo i stočarstvo u proizvodnji zdravstveno bezbedne hrane, Herceg Novi, 21-25. juni, 39.
- STAVRIC S., KORNEGAY E.T. (1995): Microbial probiotics for pigs and poultry. In: WALLACE R.J., CHESSON A. (eds), *Biotechnology in animal feeds and animal feeding.* VCH Verlagsgesellschaft mbH., Wienheim, RFN, 206-231.
- TIZARD I. R., CARPENTER R.H., McANALLEY B.H., KEMP M.C. (1989): The biological activities of mannans and related complex carbohydrates. *Mol. Biother.*, 1, 290.
- ZIMMERMAN D.R. (1985): Role of subtherapeutic levels of antimicrobials in pig production. *Journal of Animal Science*, 62, suppl 3, 6-17.
- ŽIVKOVIĆ B., MIGDAL W., FABJAN M., KOVČIN S., RADOVIĆ Č., KOSOVAC O., TODOROVIĆ M., JOKIĆ Ž. (2004): Nutritivna vrednost probiotika u ishrani svinja u tovu. *Biotehnologija u stočarstvu*, 20, 1-2, 51-58.
- ŽIVKOVIĆ B., W. MIGDAL, M. FABJAN, S. KOVČIN (2001): Possibilities for the use of probiotic Paciflor C 10 in the nutrition of weaned piglets. International Scientific Conference "Animal Science in the XXI Century", October, Krakow, Poland, 231-237.
- ŽIVKOVIĆ B., MIGDAL W., FABJAN M., RADOVIĆ Č. (2003): Probiotic in nutrition of sows and suckling piglets. International Scientific Conference "Science for Practice", September, Kraków, Poland, *Roczniki Naukowe Zootechniki*, 17/1, Supplement, 309-313.
- ŽIVKOVIĆ B., MIGDAL W., PETROVIĆ M., RADOVIĆ Č., KOSOVAC O., FABJAN M., JOSIPOVIĆ S., MALETIĆ R. (2006a): The effect of introduction of some additives in fattening pig diets on slaughter results and meat quality.

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International Conference »Linking up the meat chain: ensuring quality and safety for the consumers«, Kraków, Poland, 19-20 October, British Society of Animal Science, 1, Supplement 1, 60-61.

ŽIVKOVIĆ B., MIGDAL W., RADOVIĆ Č., FABJAN M., KOSOVAC O. (2005): Probiotic in gilt nutrition. *Biotechnology In Animal Husbandry*, 21, 5-6, 169-174.

ŽIVKOVIĆ B., NIKIĆ D., MIGDAL W., RADOVIĆ Č., FABJAN M., KOSOVAC O., PEJČIĆ S. (2006b): Probiotik Beta Plus u ishrani krmača i prasadi. *Biotehnologija u stočarstvu*, 22, 1-2, 109-117.

ŽIVKOVIĆ B., STANOJLOVIĆ R. (2006): Probiotici Lacture i Microbond u ishrani svinja u tovu. *Eurofarmer*, 11-12, 43-45.

ŽIVKOVIĆ B., STANOJLOVIĆ R., MIGDAL W., RADOVIĆ Č., FABJAN M., KOSOVAC O., TODOROVIĆ-JOKSIMOVIĆ M. (2006): Additives Lacture and Microbond in nutrition of sows and piglets. *Krmiva, Zagreb*, 48, 251-259.

WHITE L.A., NEWMAN M.C., CROMWELL G.L., LINDEMAN M.D. (2002): Brewers dried yeast as a source of mannan oligosaccharides for weanling pigs. *Journal of Animal Science*, 80, 2619-2628.

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