

14th
INTERNATIONAL
SYMPOSIUM

MODERN
TRENDS
IN LIVESTOCK
PRODUCTION



P R O C E E D I N G S

4 - 6 October 2023, Belgrade, Serbia

Institute for Animal Husbandry
Belgrade - Zemun, SERBIA

**14th
INTERNATIONAL
SYMPOSIUM**

**MODERN
TRENDS
IN LIVESTOCK
PRODUCTION**



4 - 6 October 2023, Belgrade, Serbia

PATRONS

Ministry of Science, Technological Development
and Innovation of the Republic of Serbia

Ministry of Agriculture, Forestry and Water Management
of the Republic of Serbia

ORGANIZER

Institute for Animal Husbandry

Autoput 16, P. Box. 23,

11080, Belgrade-Zemun, Serbia

Tel: +381 11 2691 611; +381 11 2670 121; +381 11 2670 541;

Fax: + 381 11 2670 164;

PUBLISHER

Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Editor

Zdenka Škrbić, PhD, Principal Research Fellow

Institute for Animal Husbandry, Belgrade-Zemun

The Proceedings is printed by the Institute for Animal Husbandry,
Belgrade, 2023



biotechnology.izs@gmail.com

www.istocar.bg.ac.rs

Circulation 100 copies.

ISBN 978-86-82431-80-0

INTERNATIONAL SCIENTIFIC COMMITTEE

CHAIRMAN

Prof. Dr. **Giacomo Biagi**,
Department of Veterinary Medical Sciences,
University of Bologna, Italy

SECRETARY

Dr. **Nikola Delić**,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

MEMBERS

Dr. **Dragana Ružić-Muslić**,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. **Vlada Pantelić**,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. **Aleksandar Stanojković**,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. **Miloš Lukić**,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. **Zdenka Škrbić**,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. **Čedomir Radović**,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Prof. Dr. **Marjeta Čandek-Potokar**,
Agricultural Institute of Slovenia, Ljubljana, Slovenia

Dr. **Giuseppe Bee**,
Agroscope Posieux, Posieux, Switzerland

Prof. Dr. **Zoran Stanimirović**,
University of Belgrade, Faculty of Veterinary Medicine, Serbia

Prof. Dr. **Stayka Laleva**,
Agricultural Institute, Stara Zagora, Bulgaria

Prof. Dr. **Maya Ignatova**,
Institute of Animal Science, Kostinbrod, Bulgaria



INTERNATIONAL SCIENTIFIC COMMITTEE

- Dr. Ivan Bošnjak,**
Ministry of Human and Minority Rights and Social Dialogue, Serbia
- Dr. Veselin Petričević,**
Institute for Animal Husbandry, Belgrade-Zemun, Serbia
- Dr. Dušica Ostojić Andrić,**
Institute for Animal Husbandry, Belgrade-Zemun, Serbia
- Prof. Dr. Galia Zamaratskaia,**
Department of Molecular Sciences, BioCenter,
Swedish University of Agricultural Sciences, Uppsala, Sweden
- Dr. Dragan Nikšić,**
Institute for Animal Husbandry, Belgrade-Zemun, Serbia
- Dr. Ljiljana Samolovac,**
Institute for Animal Husbandry, Belgrade-Zemun, Serbia
- Prof. Dr. Lidiya Perić,**
University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia
- Prof. Dr. Wladyslav Migdal,**
Department of Animal Product Technology,
University of Agriculture in Kraków, Poland
- Dr. Dobrila Jakić-Dimić,**
Scientific Veterinary Institute of Serbia, Serbia
- Prof. Dr. Yalçın Bozkurt,**
Isparta University of Applied Science,
Department of Animal Science, Isparta, Türkiye
- Dr. Snežana Mladenović Drinić,**
Maize Research Institute „Zemun Polje“, Belgrade, Serbia
- Dr. Jelena Aleksić,**
Institute of Molecular Genetics and Genetic Engineering, Serbia
- Dr. Nikola Stanišić,**
Institute for Animal Husbandry, Belgrade - Zemun, Serbia
- Dr. Jack Bergsma,**
Royal Avebe, The Netherlands



INTERNATIONAL SCIENTIFIC COMMITTEE

Dr. **Sam Millet**,

ILVO, Flanders Research Institute for Agriculture, Fisheries and Food, Belgium

Prof. Dr. **Antonella Dalle Zotte**,

Department of Animal Medicine, University of Padova, Italy

Prof. Dr. **Snežana Trivunović**,

University of Novi Sad, Faculty of Agriculture, Serbia

Prof. Dr. **Predrag Perišić**,

University of Belgrade, Faculty of Agriculture, Serbia

Prof. Dr. **Martin Škrlep**,

Agricultural Institute of Slovenia, Slovenia

Dr. **Violeta Caro Petrović**,

Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. **Nevena Maksimović**,

Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Prof. Dr. **Vesna Gantner**,

Josip Juraj Strossmayer University of Osijek,

Faculty of Agrobiotechnical Sciences, Osijek, Croatia

Dr. **Maria Munoz**,

Departamento Mejora Genética Animal,

INIA, Spain

Dr. **Violeta Mandić**,

Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Prof. Dr. **Pero Mijić**,

Josip Juraj Strossmayer University of Osijek,

Faculty of Agrobiotechnical Sciences, Osijek, Croatia

Prof. Dr. **Zoran Luković**,

University of Zagreb, Faculty of Agriculture,

Department of Animal Science and Technology, Croatia

Prof. Dr. **Dubravko Škorput**,

University of Zagreb, Faculty of Agriculture,

Department of Animal Science and Technology, Croatia

Prof. Dr. **Aleksandar Simić**,

University of Belgrade, Faculty of Agriculture, Serbia

Prof. Dr. **Simeon Rakonjac**,

University of Kragujevac, Faculty of Agronomy, Serbia



INTERNATIONAL SCIENTIFIC COMMITTEE

Dr. Jasna Prodanov-Radulović,
Scientific Veterinary Institute “Novi Sad”, Serbia

Prof. Dr. Rosa Nieto,
Departament of Physiology and Biochemistry of Animal
Nutrition Estacion Experimental del Zaidín, CSIC Armilla,
Granada, Spain

Dr. Jordan Marković,
Institute for Forage Crops, Kruševac, Serbia

Dr. Juan M. García Casco,
Departamento Mejora Genética Animal,
INIA, Madrid, Spain

Dr. Slavica Stanković,
Maize Research Institute „Zemun Polje“, Belgrade, Serbia

Dr. Vesna S. Krnjaja,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia



ORGANIZING COMMITTEE

CHAIRMAN

Dr. Nikola Delić,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

SECRETARY

Dr. Maja Petričević,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

MEMBERS

Dr. Marina Lazarević,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. Marija Gogić,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. Vladimir Živković,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. Nenad Mičić,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Dr. Vesna Dragičević,
Maize Research Institute „Zemun Polje“, Belgrade, Serbia

Prof. Dr. **Tanja Vasić,**
Faculty of Agriculture, University of Niš, Serbia

Prof. Dr. **Tanja Petrović,**
Faculty of Agriculture, University of Belgrade, Serbia

Dr. Nataša Tolimir,
Institute for Science Application in Agriculture, Serbia



SYMPOSIUM SECRETARIAT

CHAIRMAN

Dr. Maja Petričević,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

MEMBERS

Slavko Maletić, grad. econ.
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Olga Devečerski, grad. prof.
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Bogdan Cekić, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Miloš Marinković, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Nenad Stojiljković, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Ivan Ćosić, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Tamara Stameniċ, MPharmSc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Tanja Keškić, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Danijel Milenković, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Nemanja Lečić, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia

Aleksandra Petrović, Msc,
Institute for Animal Husbandry, Belgrade-Zemun, Serbia





Address:

Institute for Animal Husbandry,
Autoput 16, P. Box 23,
11080, Belgrade-Zemun, Serbia

Tel:

+381 11 2691 611

+381 11 2670 121

+381 11 2670 541

Fax:

+381 11 2670 164

E-mail: biotechnology.izs@gmail.com

www.istocar.bg.ac.rs

CONTENT

Martin Wähner

THE SCIENTIFIC CONFERENCES OF THE ZEMUN INSTITUTE - A
REVIEW AND OUTLOOK (Germany)..... 1-7

Vesna Gantner, Maja Gregić, Čedomir Radović

SUSTAINABILITY OF A PLANT-BASED DIET(Croatia, Serbia).... 8-23

*Federica Sportelli, Benedetta Delfini, Costanza Delsante, Carla Giuditta
Vecchiato, Carlo Pinna, Giacomo Biagi*

THE INFLUENCE OF NUTRITION ON CANINE BEHAVIOR AND
THE ROLE OF THE GUT-BRAIN AXIS: A COMPREHENSIVE
REVIEW (Italy)..... 24-39

Giuseppe Bee, Steve Jacot, George Guex, Claudine Biolley

EFFECT OF THE FATTY ACID COMPOSITION OF THE
MATERNAL DIETS OF SWISS LARGE WHITE SOWS ON THE
FATTY ACID COMPOSITION OF THE BACKFAT OF THE
PROGENY (Switzerland)..... 40-60

Sam Millet, Sophie Goethals

BALANCING AMINO ACID LEVELS IN PIGLET DIETS (Belgium) 61-72

*Zaira Pardo, Ignacio Fernández-Fígares, Manuel Lachica, Isabel
Seiquer, Luis Lara, Consolación García-Contreras, Fernando Sánchez-
Esquiliche, Rosa Nieto*

HEAT STRESS EFFECTS ON IBERIAN PIG GROWTH AND
PRODUCTIVITY (Spain)..... 73-82

*Vladimir Živković, Wladyslaw Migdal, Lukasz Migdal, Marija Gogić,
Nenad Stojiljković, Aleksandra Petrović, Čedomir Radović*

ENHANCING PIGLET GROWTH WITH LIVE YEAST: A
NUTRITIONAL SUPPLEMENT STUDY (Serbia, Poland)..... 83-92

*Bojana Savić, Martin Škrlep, Klavdija Poklukar, Nina Batorek Lukač,
Marjeta Čandek-Potokar*

VARIATION IN CARCASS, MEAT AND FAT QUALITY OF
AUTOCHTHONOUS BREED IN CONVENTIONAL AND ORGANIC
PRODUCTION SYSTEM (Slovenia)..... 93-103

<i>Galia Zamaratskaia, Ayaz Mammadov, Javid Ojaghi, Simon Tobias Höxter, Oksana Kravchenko, Nataliia Hryshchenko, Mykhailo Matvieiev, Elina Åsbjer, Birgitta Staaf Larsson, Svitlana Usenko, Anders H. Karlsson, Hallvard Wie, Iveta Kocina, Liene Ansone, Vytautas Ribikauskas, David Richard Arney, Ragnar Leming, Francesca Carnovale, Andriy Getya</i> ATTITUDES OF CONSUMERS TOWARDS ANIMAL WELFARE IN UKRAINE AND AZERBAIJAN (Sweden, Ukraine, Azerbaijan, Latvia, Lithuania, Estonia).....	104-113
<i>Ljiljana Samolovac, Dragan Nikšić, Dušica Ostojić Andrić, Vladimir Živković, Dragan Stanojević, Vlada Pantelić, Nenad Mičić</i> ORGANIZATION OF CATTLE PRODUCTION IN CONDITIONS OF CLIMATE CHANGE (Serbia).....	114-128
<i>Nevena Maksimović, Dragana Ružić-Muslić, Violeta Caro Petrović, Bogdan Cekić, Ivan Ćosić, Nemanja Lečić, Nikola Stanišić</i> GOATS AND CLIMATE RESILIENCE (Serbia).....	129-143
<i>Fatmagül Tolun, Ergün Demir</i> CARBON CAPTURE TECHNOLOGIES FOR LIVESTOCK FARMS (Türkiye).....	144-156
<i>Slavča Hristov, Marko Cincović, Branislav Stanković, Radojica Đoković, Dušica Ostojić Andrić, Ljiljana Samolovac, Dimitar Nakov</i> DETERMINATION OF NEW WELFARE AND STRESS INDICATORS OF THE ANIMALS ON CATTLE AND PIG FARMS BASED ON DIFFERENT PUBLICATIONS (Serbia, North Macedonia)	157-167
<i>Branislav Stanković, Slavča Hristov, Marko Cincović, Radojica Đoković, Dušica Ostojić Andrić, Ivana Milošević-Stanković, Dimitar Nakov</i> DETERMINATION OF NEW BIOSECURITY INDICATORS ON CATTLE AND PIG FARMS BASED ON DIFFERENT PUBLICATIONS (Serbia, North Macedonia).....	168-181
<i>Simeon Rakonjac, Snežana Bogosavljević-Bošković, Zdenka Škrbić, Miloš Lukić, Vladimir Dosković, Veselin Petričević, Milun D. Petrović</i> ORGANIC POULTRY PRODUCTION: GENOTYPE CHOICE AND WELFARE (Serbia).....	182-192
<i>Marko Pajić, Slobodan Knežević, Jelena Maletić, Sava Spiridonović, Biljana Đurđević, Dalibor Todorović, Dušica Ostojić Andrić</i> ASSESSMENT OF THE CURRENT STATE OF BIOSECURITY MEASURES ON BROILER CHICKEN FARMS WITH DIFFERENT CAPACITIES IN VOJVODINA (Serbia).....	193-205

<i>Maria Muñoz, Ángel M. Martínez-Móntes, Almudena Fernández, Josep Maria Folch, Ana I. Fernández</i> EXPLORING PORCINE GROWTH AND FATNESS THROUGH LIVER TRANSCRIPTOME ANALYSES IN DIFFERENT IBERIAN GENETIC BACKGROUNDS (Spain).....	206-213
<i>Martin Škrlep Nina Batorek Lukač</i> ADVANTAGES AND DRAWBACKS OF REARING OF ENTIRE MALE AND IMMUNOCASTRATED PIGS (Slovenia).....	214-231
<i>Dubravko Škorput, Danijel Karolyi, Ana Kaić, Zoran Luković</i> OPTIMUM CONTRIBUTION SELECTION: PRACTICAL IMPLEMENTATION IN BLACK SLAVONIAN AND BANIIJA SPOTTED PIG (Croatia).....	232-240
<i>Fernando Sánchez-Esquiliche, Patricia Palma-Granados, Luisa Ramírez Hidalgo, Alberto Márquez, María Muñoz, Juan M. García Casco</i> IMPROVING THE REPRODUCTIVE CHARACTERISTICS OF THE PUREBRED IBERIAN PIG: A CHALLENGING ENDEAVOR (Spain)	241-250
<i>Aleksandar Stanojković, Nikola Stanišić, Nikola Delić, Ivan Bošnjak, Violeta Mandić, Aleksandra Stanojković-Sebić, Jakov Nišavić</i> STREPTOCOCCUS SUIS, TWO-FACED GAME CHANGER (Serbia)	251-266
<i>Jasna Prodanov-Radulović, Jelena Petrović, Siniša Grubač, Mijana Nešković, Slavča Hristov, Jovan Bojkovski</i> RELEVANT BIOSECURITY MEASURES TO PREVENT THE SPREAD OF AFRICAN SWINE FEVER IN THE DOMESTIC PIG PRODUCTION SECTOR IN SERBIA (Serbia).....	267-275
<i>Igor M. Stojanov, Doroteja A. Maričić, Radomir D. Ratajac, Jasna Z. Prodanov Radulović, Stevan G. Rodić, Jelena B. Apić, Ivan M. Pušić</i> SIGNIFICANCE OF LISTERIA ISOLATES IN ABORTED MATERIALS FROM COWS (Serbia).....	276-285
<i>Ivan Pavlović, Stanko Minić, Violeta Caro Petrović, Milan P. Petrović, Ivan Dobrosavljević, Nemanja Zdravković, Jovan Bojkovski, Ana Vasić, Marija Pavlović, Aleksandra Tasić</i> COENUROSIS OF SHEEP IN SERBIA - CASE REPORT (Serbia).....	286-296
<i>Yunus Emre Ata, Kemal Çelik</i> INVESTIGATION OF THE USE OF PROPOLIS IN BROILER FEEDS AND ITS EFFECTS ON HEALTH AND PERFORMANCE PARAMETERS (Türkiye).....	297-310

<i>Muhittin Zengin, Ergün Demir, Abdulkadir Keskin</i> CURRENT APPROACHES TO THE RELATIONSHIP OF ZEARALENONE AND FERTILITY IN LIVESTOCK (Türkiye).....	311-324
<i>Jack Bergsma</i> THE USE OF STARCH IN THE MEAT PROCESSING INDUSTRY (The Netherlands).....	325-334
<i>Nikola Stanišić, Nikola Delić, Slaviša Stajić, Maja Petričević, Slobodan Lilić, Tamara Stamenić, Aleksandar Stanojković</i> EFFECT OF FAT LEVEL ON QUALITY CHARACTERISTICS OF TRADITIONAL SUCUK SAUSAGES. PART 1: PHYSICO- CHEMICAL CHANGES DURING PRODUCTION (Serbia).....	335-345
<i>Nikola Delić, Nikola Stanišić, Aleksandar Stanojković, Maja Petričević, Tamara Stamenić, Nevena Maksimović, Tanja Keškić</i> EFFECT OF FAT LEVEL ON QUALITY CHARACTERISTICS OF TRADITIONAL SUCUK SAUSAGES. PART 2: TEXTURE, COLOUR AND SENSORY QUALITY (Serbia).....	346-354
<i>Władysław Migdał, Čedomir Radović, Vladimir Živković, Maria Walczycka, Anna Migdał, Lukasz Migdał</i> MEAT OF NATIVE PIGS BREEDS AS A RAW MATERIAL FOR TRADITIONAL PRODUCTS OBTAINED IN SERBIA AND POLAND (Poland, Serbia).....	355-374
<i>Ana Kaić, Dubravko Škorput, Danijel Karolyi, Zoran Luković</i> ASSESSMENT OF WATER-HOLDING CAPACITY IN DIFFERENT MEATS USING EZ-DRIPLOSS METHOD: A REVIEW OF KEY METHODOLOGICAL FACTORS (Croatia).....	375-383
<i>Yalcin Bozkurt, Mevlüt Türk, Sabahattin Albayrak</i> PATH COEFFICIENT ANALYSIS BETWEEN BODY WEIGHT AND SOME REAL-TIME BODY MEASUREMENTS OF GRAZING CATTLE ON DIFFERENT ARTIFICIAL PASTURES (Türkiye).....	384-395
<i>Jordan Marković, Vladimir Zornić, Ratibor Štrbanović</i> EFFECT OF CONDENSED TANNINS CONCENTRATIONS ON PROTEIN DEGRADABILITY OF RED CLOVER, ITALIAN RYEGRASS AND THEIR MIXTURES (Serbia).....	396-407
<i>Marina Lazarević, Vlada Pantelić, Dragan Stanojević, Dragan Nikšić, Nevena Maksimović, Miloš Marinković, Ljiljana Samolovac</i> TREND OF MILK YIELD TRAITS OF BULL MOTHERS OF THE HOLSTEIN-FRIESIAN BREED (Serbia).....	408-417

Tina Bobić, Pero Mijić, Vesna Gantner, Mirjana Baban, Maja Gregić
FARMER EXPERIENCE IN TRANSITION FROM CONVENTIONAL
TO ROBOTIC MILKING (Croatia)..... 418-424

Savaş Atasever
BROMOTYMOL BLUE TEST SCORES FOR DETECTING RAW
MILK QUALITY OF BUCKET MILK OF JERSEY COWS (Türkiye) 425-431

*Amila Milišić, Zlatan Sarić, Lejla Biber, Amila Oras, Munevera Begić,
Tarik Dizdarević, Miroljub Barać, Svijetlana Sakić-Dizdarević*
PRODUCTION AND QUALITY ASPECTS OF PROBIOTIC
FERMENTED MILK WITH ADDITION OF HONEY (Bosnia and
Herzegovina, Serbia)..... 432-440

POSTER SECTION

*Milun D. Petrović, Vladan Bogdanović, Snežana Bogosavljević-Bošković,
Simeon Rakonjac, Radojica Đoković, Radica Đedović, Miloš Ži. Petrović*
EFFECT OF SYSTEMATIC FACTORS ON MILK PRODUCTION
PER MILKING, PRODUCTIVE AND LIFETIME DAY IN
SIMMENTAL COWS (Serbia)..... 441-449

*Vesna Gantner, Ivana Jožef, Vera Popović, Maja Gregić, Dragan Solić,
Klemen Potočnik*
THE EFFECT OF MASTITIS PREVALENCE RISK ON THE DAILY
PRODUCTION OF DAIRY COWS CONCERNING THE MILK
RECORDING YEAR (Croatia, Slovenia)..... 450-459

*Dušica Ostojić Andrić, Slavča Hristov, Branislav Stanković, Violeta Caro
Petrović, Marko Pajić, Dragan Nikšić, Ljiljana Samolovac, Miloš
Marinković*
MEDICINAL AND AROMATIC PLANTS IN LIVESTOCK
FARMING: A PROMISING APPROACH FOR BOOSTING HEALTH
AND PERFORMANCE (Serbia)..... 460-475

Dragan Dokić, Vera Popović, Maja Gregić, Vesna Gantner
IMPROVING THE DEVELOPMENT OF THE COMPETITIVENESS
OF PIG AND CATTLE PRODUCTION IN THE REPUBLIC OF
CROATIA BY APPLYING GENERIC STRATEGIES (Croatia)..... 476-483

Maja Gregić, Tina Bobić, Dragan Dokić, Vesna Gantner
THERMOREGULATION OF SPORTS HORSES (Croatia)..... 484-492

<i>Ivan Vlahek, Nevena Maksimović, Aneta Piplica, Maja Maurić Maljković, Nikola Delić, Marina Lazarević, Velimir Sušić</i> POPULATION TRENDS OF GOATS IN SERBIA AND CROATIA FROM 2012 TO 2021 (Croatia, Serbia).....	493-507
<i>Alkan Çağlı, Hasan Coğan, Murat Yilmaz</i> COMPARISON OF BODY WEIGHT, FAMACHA © BCS AND HAIR SCORES IN SAANEN GOATS DURING PREGNANCY AND BIRTH PERIOD (Türkiye).....	508-518
<i>Bogdan Cekić, Dragana Ružić Muslić, Nevena Maksimović, Violeta Caro Petrović, Ivan Čosić, Nemanja Lečić, Zsolt Becskei</i> NEW ASPECTS IN RISK STATUS EVALUATION OF SMALL RUMINANT LOCAL BREEDS IN SERBIA (Serbia).....	519-530
<i>Maria Babetsa, Evangelia D. Apostolidi, Loukia V. Ekateriniadou, Evridiki Boukouvala</i> PRNP GENE POLYMORPHISMS IN HEALTHY GREEK SHEEP FROM 2017 TO 2022 - NATIONAL DATABASE FROM RESISTANT RAMS (Greece).....	531-539
<i>Nikola Metodiev</i> THE EFFECT OF THE APPLICATION OF MELATONIN IMPLANTS IN THE SPRING ON THE MANIFESTATION OF ESTRUS AND FERTILITY IN ILE DE FRANCE SHEEP (Bulgaria).....	540-546
<i>Klavdija Poklukar, Marjeta Čandek-Potokar, Nina Batorek Lukač, Marie-José Mercat, David Picard Druet, Martin Škrlep</i> GENE POLYMORPHISMS FREQUENCIES IN KRŠKOPOLJE PIG BREED (Slovenia, France).....	547-555
<i>Klavdija Poklukar, Marjeta Čandek-Potokar, Nina Batorek Lukač, Marie-José Mercat, David Picard Druet, Martin Škrlep</i> THE EFFECT OF PRKAG3 AND RYR1 GENE ON MEAT QUALITY TRAITS IN THE LOCAL KRŠKOPOLJE PIG BREED (Slovenia, France).....	556-565
<i>Vesna Krnjaja, Violeta Mandić, Slavica Stanković, Ana Obradović, Tanja Petrović, Tanja Vasić, Marina Lazarević</i> FUSARIUM AND DEOXYNIVALENOL CONTAMINATION OF WINTER WHEAT DEPENDING ON GROWING SEASON AND CULTIVAR (Serbia).....	566-576

***STREPTOCOCCUS SUIIS*, TWO-FACED GAME CHANGER**

**Aleksandar Stanojković¹, Nikola Stanišić¹, Nikola Delić¹, Ivan Bošnjak³,
Violeta Mandić¹, Aleksandra Stanojković-Sebić², Jakov Nišavić⁴**

¹ Institute for Animal Husbandry, Autoput 16, 11080, Belgrade-Zemun, Republic of Serbia.

² Institute of Soil Science, Teodora Drajzera 7, 11000, Belgrade, Republic of Serbia

³ Ministry for Human and Minority Rights and Social Dialogue, Bulevar Mihajlo Pupin 2, 11070 Novi Beograd, Republic of Serbia

⁴ Faculty of Veterinary Medicine, Bulevar Oslobođenja 18, 11000, Belgrade, Republic of Serbia

Corresponding author: Aleksandar Stanojković, izs.aleksandar@gmail.com

Invited paper

Abstract: *Streptococcus suis* infection is one of the major health problems in the swine industry worldwide. During the last decade, the number of reported human cases due to *S. suis* has dramatically increased, and while most sporadic human cases of infection appear to be due to close occupational contact with pigs/pork products. *S. suis* infection is considered to be multifactorial, with transition from subclinical to clinical that depends on many factors. These factors can be divided in two groups, host-based and external factors. Pathogenesis of *S. suis* infection can be divided into 4 phases: adherence to and colonisation of mucosal and epithelial surfaces, invasion into deeper tissues and entering the bloodstream, crossing blood-brain barrier and inflammation. *S. suis* virulence-associated factors are divided into the following 4 groups: surface/secreted elements, enzymes (such as including proteases), transcription factors and regulatory systems and other factors (such as transporting and secreting systems). Therefore significant research support is needed to obtain a vaccine as a valuable and universal protection against disease caused by *S. suis* strains and thus national and international support will be crucial for the aim many researchers hope for.

Key words: *Streptococcus suis*, pigs, commensal, pathogen, virulence factors

Introduction

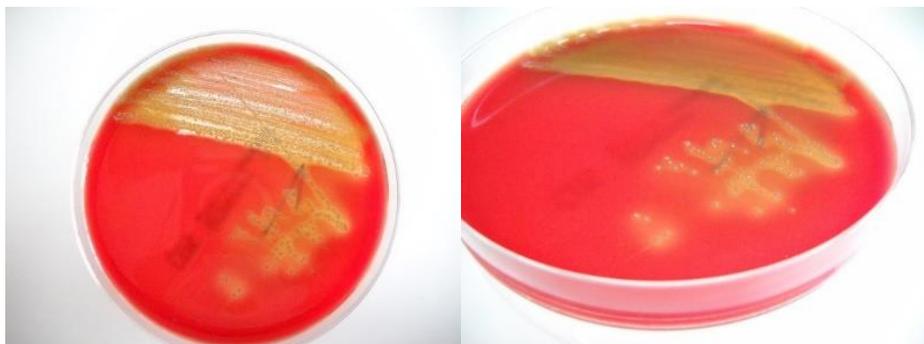
Streptococcus (S. suis) is a commensal of the swine respiratory system, in particular of the tonsils and nasal cavities, but it can also cause serious infections with high mortality rate.

Streptococcus suis infection is one of the major health problems in the swine industry worldwide. This pathogen is the most prominent cause of meningitis and septicemia in the porcine industry, however, other pathological conditions have also been described, such as arthritis, endocarditis, pneumonia, and septicemia with sudden death.

S. suis is primarily considered a major swine pathogen, but it has been increasingly isolated from a wide range of mammalian species, birds and even fish species. These findings suggest the existence of complex epidemiological patterns of the infection, since other animal species might also be a source of swine infection (Gottschalk *et al.*, 2010b). Human *S. suis* infections have usually been considered sporadic (Arends and Zanen, 1988). During the last decade, the number of reported human cases due to *S. suis* has dramatically increased, and while most sporadic human cases of infection appear to be due to close occupational contact with pigs/pork products, particularly in Western countries (farmers, veterinarians, butchers, food processing workers, etc.), two epidemics were recorded in China in 1998 and 2005 (Goyette-Desjardins *et al.*, 2014). However, the important outbreak in China that occurred in 2005 and that affected more than 200 people with a mortality rate of nearly 20% changed the perspective on the threat of *S. suis* to human health.

Microorganism characteristics, number and distribution of serotypes

Streptococcus suis is a facultative anaerobic, Gram-positive coccoid bacterium that has the ability of capsule synthesis and secretes hemolysin. The cell wall antigenic components of *S. suis* are similar to those displayed by group D streptococci (Stanojković *et al.*, 2012). However, *S. suis* is not genetically associated with group D streptococci (Kilpper-Balz and Schleifer, 1987). The organism grows well on media usually used for isolation of streptococci, most frequently sheep blood agar, and forms glistening, round, slightly grey alpha haemolytic colonies (Picture 1). *S. suis* has very variable biochemical properties (Stanojković *et al.*, 2014) and thus must be confirmed by serotyping.



Picture 1. Alpha haemolytic colonies of *Streptococcus suis* on CNA 5 % sheep blood agar (Stanojković *et al.*, 2012)

Previously, *S. suis* had been classified into 35 serotypes (serotype 1/2, and 1–34) (Higgins and Gottschalk, 1995) and then reduced to 33 serotypes because serotypes 32 and 34 were determined to be *Streptococcus orisratti*, streptococci that can be often isolated from rats (Hill *et al.*, 2005). More recently, it was proposed to remove serotypes 20, 22, 26 and 33 from the *Streptococcus suis* taxon (Tien *et al.*, 2013). Hence, it is currently considered that there are 29 true *Streptococcus suis* serotypes.

During the last 12 years, more than 4500 serologically confirmed strains recovered from diseased pigs have been reported. Globally, the most dominant serotypes isolates from clinical cases in pigs are serotypes 2, 9, 3, 1/2 and 7, while 15.5% were so called non-typable strains. However, there is clear geographical distribution of serotypes.

Goyette-Desjardins *et al.* (2014) summarize strain prevalence in Europe and America. In Canada the most prevalent serotype is serotype 2, while in United States serotype 3 is the most prevalent. In these countries there is only a slight difference in percentages of prevalent strains, demonstrating similar distribution of serotypes when data from Canada and the USA are combined. Both, serotypes 2 and 3 are the most prevalent from diseased pigs with 24.3% and 21.0% prevalence respectively, followed by serotypes 1/2, 8 and 7 (Goyette-Desjardins *et al.*, 2014). This can be explained by easy and free movement of animals from United states to Canada and vice versa. In South America, all results came from Brasil, stating that serotype 2 is the most prevalent with 57.6% reported cases followed by serotypes 1/2, 14, 7 and 9. In Asia, the majority of results regarding serotype affiliation came from China and South Korea. In China the most prevalent serotypes detected in infected pigs are, in decreasing order of prevalence, serotypes 2, 3 4, 7, and 8. On

the contrary, in South Korea serotype 2 had a prevalence of only 8.3%, the same as serotypes 8 and 33 while the most dominant were serotypes 3 and 4 with 29.2% and 20.8% respectively, while serotypes 16 and 22 had distribution of 4.1%. Other Asian countries reported many human cases of disease but strains isolated from pigs only refer to slaughterhouses and healthy pigs. Similarly, in Japan there have been 10 human *S. suis* cases reported but studies on the distribution of isolates from ill pigs have not been published ately and all of the research dates before 1987. In Cambodia, Philippines, Laos and Singapore, human cases were diagnosed recently but there are no data available on the epidemiology of *S. suis* infections in pigs.

In Europe, the largest number of *S. suis* serotypes isolated from clinically ill pigs belongs to serotypes 1 to 8 (Reams *et al.*, 1996; Higinis and Gottschalk, 2005). Most of the *S. suis* serotype distribution reports date before year 2000. *S. suis* serotype 2 was the most common in clinical cases in Italy, France and Spain, whereas serotype 9 was more frequent in the Netherlands, Germany and Belgium. Recent conducted reaserch on serotype distribution in Spain suggest that serotype 2 is no longer the most prevalent serotype, and that serotype 9 is the one most frequently isolated from diseased pigs. Behind serotype 9 is serotype 2, followed by serotypes 7, 8 and 3 (Luque *et al.*, 2010). In Netherlands, serotype 9 was the most prevalent in data collected between 2002-2007 followed by serotypes 2, 7, 1 and 4. Contrary to the fact that serotype 9 becomes most prevalent in some countries, there were no human cases reported that were associated with this serotype. In Belgium and United Kingdom, serotype 1 was the predominant in ill pigs while in Denmark serotype 7 was the most frequent one. In Southern Europe, serotype distribution was done in Serbia where serotype 2 was the only serotype found in piglets that had clinical symptoms of meningitis (Stanojkovic *et al.*, 2015). Beside that various *S. suis* serotypes were found in healthy animals (Stanojković, 2012).

***S. suis* infection in pigs**

The natural habitat of *S. suis* is the upper respiratory tract of pigs, more particularly the tonsils and nasal cavities, but also the genital and digestive tracts (Goyette-Desjardins *et al.*, 2014). Almost 100% of pig farms worldwide have carrier animals, and that puts *S. suis* as one of the most important bacterial pig pathogens with quite established infection patterns.

Transmission of *S. suis* among animals is considered to be mainly through the respiratory route. Indeed, investigation of presence of alpha haemolytic streptococci, enterococci and streptococci-like bacteria in tonsil and nose swabs of

clinically healthy pigs in one research (*Stanojković et al., 2012*) showed that most species belonged to *S. suis* (64%).

The sow is also a source of infection. Gilts and sows may harbor *S. suis* in the uterus or vagina, but no male reproductive organs have been shown to be infected. Piglets born to sows with uterine or vaginal *S. suis* infections become infected at birth, before birth, or soon after birth (*Robertson and Blackmore, 1989*), but mostly when passing through the birth canal.

Transmission of virulent strains between herds usually occurs by the movement of healthy carrier animals. The introduction of carrier pigs harboring virulent strains (breeding gilts, boars, weaners) into a noninfected recipient herd may result in the subsequent onset of disease in weaners and/or growing pigs (*Higgins and Gottschalk, 2005*). Horizontal transmission is important especially during outbreaks when diseased animals shed higher numbers of bacteria, increasing transmission by direct contact or aerosol (*Cloutier et al., 2003*).

S. suis type 1 is an important contaminant of feces, dust and water. In water, the organism survives for 10 min at 60°C and for 2 h at 50°C. At 48°C, *S. suis* can survive in carcasses for 6 weeks (*Clifton-Hadley et al., 1986*). At 0°C, the organism can survive for 1 month in dust and for over 3 months in feces, whereas at 25°C, it can survive for 24 h in dust and for 8 days in feces. *Dee and Corey (1993)* have also been shown that transmission of *S. suis* strains can be through fomites, such as manure-covered work boots and needles. *S. suis* can be inactivated using many disinfectants, such as diluted bleach. Organic matter reduces effectiveness of chemical disinfectants and should be completely removed with thorough washing prior to application. Even though *S. suis* survives in water up to 2 hours at 50°C but only 10 minutes at 60°C, use of heated pressure washers compared with non-heated is of limited value since water cools rapidly on surfaces negating potential benefit (*Clifton-Hadley and Enright 1984*).

Vectors of *S. suis* can play a role in disease transmission. Houseflies can carry *S. suis* strains for 2 to 5 days, and have been shown to easily transmit the disease migrating between farms (*Enright et al., 1987*). Mice can be experimentally infected orally or intranasally with *S. suis* type 2, and the transfer of organisms from orally infected mice to uninoculated mice has been established (*Williams et al., 1988; Robertson and Blackmore, 1990*). Transmission of disease between mice and pigs is believed to occur (*Williams et al., 1988*).

All categories of pigs can be affected by the disease caused by *S. suis*, including suckling piglets, older piglets and fatteners. *S. suis* carriage rates may vary between herds and can range from 0% to up to 80-100% (*Amass et al., 1997*). More than one serotype of *S. suis* often colonizes individual pigs. In one study, 31% of pigs had only one serotype of *S. suis* in their nasal cavities, 38% had two or three serotypes, and 6% had more than four serotypes (*Monter Flores et al.,*

1993). According to *Silvonen et al. (1988)* even if all the pigs in the herd are infected with some strains of *S. suis* clinically apparent disease varies and is usually below 5%. The prevalence of and the morbidity and mortality from *S. suis* vary among herds.

Even when the pig carrier rate is near 100%, the incidence of the disease varies from period to period and is usually less than 5% (*Clifton-Hadley et al., 1986*). Clinical signs can vary between herds, depending on the pathogenesis of the disease. Pigs with per acute *S. suis* infection may be found dead with no previously noticed signs of disease or die within hours of the onset of clinical signs. In the acute form of the disease, clinical signs may include fever (up to 42°C), depression, anorexia and lassitude, followed by one or more of the following: ataxia, incoordination, tremors, opisthotonus, blindness, loss of hearing, paddling, paralysis, dyspnea, convulsions, nystagmus, arthritis, lameness, erythema, and/or abortion (*Staats et al., 1997*). So, we can conclude that meningitis is the major feature of *S. suis* infection in pigs but other organs (joints, heart, lungs, reproductive organs etc.) can also be affected.

S. suis infection in humans

Different from pigs infection, the main route of entry of *S. suis* in humans is thought to be through contact of cutaneous lesions, most usually on the hands and arms, with contaminated animals, carcasses or meat, although in some cases, no wound was detected; bacteria may colonize the nasopharynx, as observed in swine; and the gastrointestinal tract, as suggested by diarrhea as a prodromal symptom (*Fongcom et al., 2001; Wertheim et al., 2009*). The outbreak in China in 2005 caused by *S. suis* affected more than 200 people, with almost 20% mortality rate. This epidemic has completely changed the perception of the danger which this pathogen presents to human health (*Stanojkovic et al., 2014*). Period of incubation ranges from just a few hours to few days (*Fongcom et al., 2001*). Just like in pigs *S. suis* produces meningitis as the main feature of disease but cases of endocarditis, pneumonia, peritonitis, arthritis and other less common clinical signs can be seen as the part of generalized septicemia (*Arends and Zanen, 1988*). Also, there have been described per acute infections related to this pathogen which were usually in the form of streptococcal toxic shock-like syndrome (STSLS) with almost 20% death cases. In Western countries, *S. suis* disease has been considered a rare event in humans. Most cases of human infection are related to close contact with meat or live animals: pig farmers, abattoir workers, persons transporting pork, meat inspectors, butchers, and veterinarian practitioners (*Tang et al., 2006*).

According to *Hoa et al. (2011)* slaughterhouse pigs are a major reservoir of *Streptococcus suis* serotype 2 capable of causing human infection. *Cheung et al.*

(2008) examined 78 samples of raw pork lean meat from retail markets and wet markets and determined that *S. suis* can be found in every sample although in different levels (MPN/g). Similar meat prevalence in Serbia (Stanojković et al., 2016) showed serotype 2 was the most isolated serotype from fresh pork with 46,1 % of isolated *S. suis* serotypes followed by serotype 9, 7, 3, 1 and 4. Slaughtered pigs had similar prevalence of *S. suis* strains just like those data reported for clinically ill pigs.

Stanojkovic et al. (2016) found that there was a significant difference in the presence of *S. suis* strains on the basis of sample collected. In above mentioned authors research hog head was highly contaminated with *S. suis* serotype 2 strains (prevalence of 25%). This result is maybe expected since *S. suis* is normal inhabitant of respiratory system such as tonsils, and also slaughtered pigs are held in that kind of position that allows water to spread bacteria from hind part of the body to the head. Same authors found that presence of *Streptococcus suis* serotype 2 in liver, kidneys, shoulder, ham, loin and belly was 20%, 12%, 5%, 5%, 5%, and 10% respectively. Have found overall prevalence of *S. suis* serotype 2 in pork of 12.8%. Same authors mentioned that prevalence of *S. suis* serotype 2 in fresh meat was 10.8% but it was not clear referring to the part of the body that fresh meat was taken from. These authors detected 15.4% prevalence of *S. suis* serotype 2 in liver and other offal and demonstrated that *S. suis* accumulates in the kidney during *S. suis* infection.

It can be concluded that processing and consuming of uncooked or partially cooked pork meat in Asian countries is major risk factor for infection.

Different from Asian countries infected persons in Western countries are usually adult males and this can be readily explained, since many acquire the disease following occupational exposure to pigs or pork products. Affected humans had usually close contact with pigs or meat and very often small cuts on their hands (Stanojkovic, 2012). Stanojkovic et al. (2012) found that *S. suis* can readily isolated from butchers knives. Also, there are reports that confirm carrier state in humans, especially abattoir workers (Sala et al., 1989; Rohas et al., 2001). Strangmann et al. (2002) determined nasopharyngeal carriage rate of *S. suis* serotype 2 in the high-risk group (butchers, abattoir workers, and meat processing employees) was 5.3%, while those without contact with pigs or pork consistently tested negative. This kind of nasopharyngeal carriage rate has also been shown in pigs (Higgins and Gottschalk, 2005).

In humans, *S. suis* usually produces a purulent meningitis but also endocarditis, cellulitis, peritonitis, rhabdomyolysis, arthritis, spondylodiscitis, pneumonia, uveitis, and endophthalmitis have also been reported (Gottschalk et al., 2010b; Wertheim et al., 2009). Also, there have been described per acute infections related to this pathogen which were usually in the form of streptococcal toxic

shock-like syndrome (STSLs) that has been associated with most of the death cases in China 2005 epidemics (Lun *et al.*, 2007). The most important often mentioned sequela of *S. suis* infection are vestibular dysfunction or unilateral or bilateral hearing loss.

***S. suis* as commensal**

S. suis is a commensal bacterium with a natural habitat being usually the tonsils and nose cavities of healthy pigs. *S. suis* two million (mega) base pairs (2 Mbp) genome contains sequences that encode variety of factors such as adhesins and enzymes which enable it to colonize pigs tonsils in cohabitation with other bacteria. Bacterial adherence is the first step and maybe crucial for development of a carrier state.

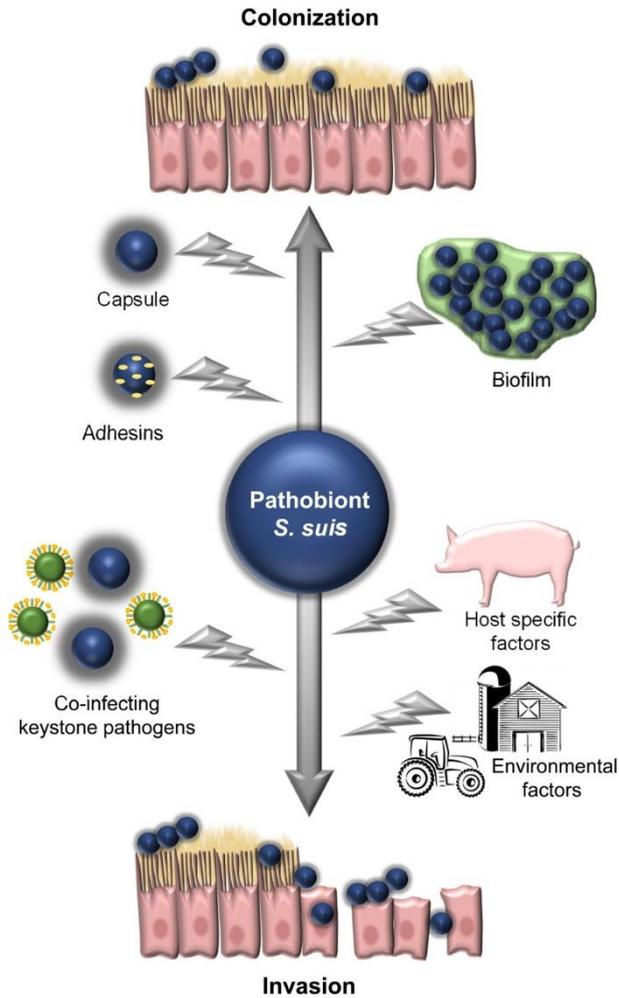
In recent years there have been many researches regarding mechanisms of adherence and tissue tropism of *S. suis*, but at the moment exact adhesin responsible for infection can not be precisely explained. Study by Chuzeville *et al.* (2017) reports that *S. suis* serotype 2 and 9 strains express genes coding for multimodal adhesion proteins known as antigen I/II (AgI/II) which in the presence of salivary glycoproteins AgI/II leads to the aggregation of *S. suis*, adherence, and colonization of the upper respiratory tract of pigs. In serotype 9, the AgI/II is responsible for aggregation and biofilm formation and these aggregated group of bacteria are partially resistant to and protected from high acid content (low pH) in the stomach which leads to colonization of the intestine (Chuzeville *et al.*, 2017).

Adhesin FhB (factor H-binding protein) of *S. suis* is responsible for binding of the blood complement H factor which results in enhanced adherence of the bacteria to epithelial and endothelial cells and protecting bacteria from complement mediated phagocytosis. (Roy *et al.*, 2016).

Polysaccharide capsule is the major factor involved in the pathogenesis of *S. suis* infection. Capsule is down regulated by *S. suis* genes and its thickness depends on the environment in which the bacterial cell resides. According to Gottschalk and Segura (2000) capsule thickness increases during epithelial invasion and adhesion and is involved in enabling *S. suis* to escape phagocytosis. Capsule synthesis is regulated by transcriptional regulator catabolite control protein A (CcpA) (Willenborg *et al.*, 2011). Non-encapsulated phenotype strains lack the *ccpA* gene.

Biofilm is one of the components that enable the bacteria to colonize tissues, resist host defense and antibacterials, but is also involved in pathogen-commensal relationship. Biofilm formation is regulated by *luxS* gene (coding for the enzyme S-ribosylhomocysteinase, LuxS). It has been reported that virulent strains of *S. suis* have a higher ability to produce biofilms than avirulent strains (Wang *et*

al., 2011a). Biofilm formation results in lower expression of virulence-associated genes with less damage to the host tissue, thus can explain the colonization of host with virulent strains while being harmless with no signs of disease.



Picture 2. *S. suis* infection (Vötsch *et al.*, 2018)

Commensal to pathogen transition

S. suis infection is considered to be multifactorial, with transition from subclinical to clinical that depends on many factors. These factors can be divided in two groups, host- based and external factors. Genetics, age, pre-existing diseases and infections, immunosuppression are one of the most prominent host-based factors. Climatic changes in the breeding objects, poor hygiene, bad ventilation, weaning, overcrowding, and other external stressors are usually the key starters of clinical infection (Vötsch *et al.*, 2018). *S. suis* strain virulence and the presence of virulence factors is also an important feature for pathogenesis. Human infection usually depends on the route of infection and immunocompetence of the human host.

Pathogenesis of *S. suis* infection can be divided into 4 phases: adherence to and colonisation of mucosal and epithelial surfaces, invasion into deeper tissues and entering the bloodstream, crossing the blood-brain barrier and inflammation. All of these phases are mediated by specific virulence factors and none of the phases will be explained here regarding their complicity and in limited knowledge for the some parts of pathogenesis.

Feng *et al.* (2014) classified *S. suis* virulence-associated factors into the following 4 groups: surface/secreted elements, enzymes (such as including proteases), transcription factors and regulatory systems and other factors (such as transporting and secreting systems). First group of the surface/secreted elements enzymes includes:

- capsular polysaccharides (*cps*);
- extracellular protein factor (*epf*);
- fibronectin binding adhesin (*fbps*);
- muramidase released protein (*mrp*);
- protein of 38 kDa localized on bacterial surface (38 kDa);
- secreted thio-activated hemolysin (suilysin)
- surface-associated subtilisin-like serine protease (*SspA*)
- histidine triade immunogenic cell surface protein (*htpS*);
- Sat surface protein (*sat*);
- serum opacity factor (*ofs*);
- surface antigen protein (*sao*);
- sortase A (*SrtA*), catalyzing cell wall sorting reaction;
- pili

The second enzyme group of virulence factors is represented by more than 20 bacterial enzymes such as:

- GlnA, glutamine synthetase (*glnA*);
- Gdh, glutamate dehydrogenase (*gdh*);
- enolase (*eno*) catalyzing dehydration of 2-phosphoglycerate to phosphoenolpyruvate enzyme catalyzing lipoteichoic acid (LTA)-d-alanylation (*dltA*);
- peptidoglycan N-acetylglucosamine deacetylase (*pgdA*);
- inosine 5-monophosphate dehydrogenase [Impdh] (*impdh*);
- N-acetylneuraminic acid (sialic acid) synthetase (*neuB*);
- UDP N-Acetylglucosamine 2-Epimerase (*neuC*)
- glyceraldehyde-3-phosphate dehydrogenase (*GAPDH*)
- DNase (112 kDa)
- IgA1 (*IgA1*) protease cleaving immunoglobulin A;
- superoxide dismutase (*sod*)
- adenosine synthase (*Ssads*)
- LuxS or S-ribosyl homocysteinase

Transcription factors include more than 15 elements which include:

- AdcR (*adcR*)
- catabolite control protein A (*ccpA*)
- ArgR (*argR*)
- Rgg (*rgg*)
- Fur (*fur*)
- PerR (*perR*)

The fourth group of transporters/secretion systems comprises following factors:

- VirA (*virA*)
- Trigger factor (*Tig*)
- FeoBA (*feoBA*)
- Type IV like-secretion system (T4SS-like system)

Conclusion

Streptococcus suis is a swine pathogen that causes important economic losses in the swine industry worldwide. This bacterium has great ability to adapt to the present host, being commensal, but also to be the cause of wide range of pathological

findings, including meningitis, septicemia and endocarditis, but also the cause of sudden death. The task of battling the disease is not easy because of the great diversity among virulent *S. suis* strains with many virulence-associated factors. It is very difficult to implement effective preventive measures in pigs but also for the persons that come into close occupational contact with pigs and pig products, especially employees of the meat industry. The goal of providing a functional vaccine against *S. suis* infection is being undertaken with promising results.

Therefore significant research support is needed to obtain vaccine as a valuable and universal protection against disease caused by *S. suis* strains and thus national and international support will be crucial for the aim many researchers hope for.

Acknowledgment

This research was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, on the basis of the Agreement on the realization and financing of scientific research work of SRO No. 451-03-47/2023-01/200022.

References

- AMASS S.F., SANMIGUEL P., CLARK L.K. (1997): Demonstration of vertical transmission of *Streptococcus suis* in swine by genomic fingerprinting. *Journal of Clinical Microbiology*, 35: 1595–1596.
- ARENDS J.P., ZANEN. (1988): Meningitis caused by *Streptococcus suis* in humans. *Rev. Infect. Dis.* 10:131-137.
- CHEUNG P-Y., LO KL., CHEUNG TT., YEUNG WH., LEUNG PH, et al. (2008): *Streptococcus suis* in retail markets: How prevalent is it in raw pork? *International Journal of Food Microbiology*, 127, 316–320.
- CHUZEVILLE S., AUGER J. P., DUMESNIL A., ROY D., LACOUTURE S., FITTIPALDI N., et al. (2017): Serotype-specific role of antigen I/II in the initial steps of the pathogenesis of the infection caused by *Streptococcus suis*. *Vet. Res.* 48:39. doi: 10.1186/s13567-017-0443-4
- CLIFTON HADLEY F.A., ENRIGHT M.R. (1984): Factors affecting the survival of *Streptococcus suis* type 2. *Veterinary Record*, 117, 585R587.
- CLIFTON HADLEY F.A., ENRIGHT M.R., ALEXANDER T.J.L.(1986): Survival of *Streptococcus suis* type 2 in pig carcasses. *Veterinary Record*, 118, 275.
- CLOUTIER G., D'ALLAIRE S., MARTINEZ G., SURPRENANT C., LACOUTURE S., GOTTSCHALK M. (2003): Epidemiology of *Streptococcus*

- suis* serotype 5 infection in a pig herd with and without clinical disease. *Veterinary Microbiology*, 97, 135–151.
- DEE S.A., COREY M.M. (1993): The survival of *Streptococcus suis* on farm and veterinary equipment. *Swine Health and Production*, 1, 17R20.
- ENRIGHT M.R., ALEXANDER T.J.L., CLIFTON HADLEY F.A. (1987): Role of houseflies (*Musca domestica*) in the epidemiology of *Streptococcus suis* type 2. *Veterinary Record*, 121.
- FENG Y., ZHANG H., WU Z., WANG S., CAO M., HU D., WANG C. (2014): *Streptococcus suis* infection: an emerging/reemerging challenge of bacterial infectious diseases? *Virulence*, 5(4): 477–497.
- FONGCOM A. et al. (2001): *Streptococcus suis* infection in northern Thailand. *J. Med. Assoc. Thai*. 84:1502-1508.
- GOTTSCHALK M., SEGURA M. (2000): The pathogenesis of the meningitis caused by *Streptococcus suis*: the unresolved questions. *Vet. Microbiol.* 76, 259–272. doi: 10.1016/S0378-1135(00)00250-9
- GOTTSCHALK M., XU J., CALZAS C., SEGURA M. (2010a): *Streptococcus suis*: a new emerging or an old neglected zoonotic pathogen? *Future Microbiol.* 5:371-391.
- GOTTSCHALK M., XU J., LECOURS M.P., GRENIER D., FITTIPALDI N., SEGURA M. (2010b): *Streptococcus suis* infections in humans: what is the prognosis for Western countries? (Part I). *Clin. Microbiol. News* 89-96.
- GOTTSCHALK M., XU J., LECOURS M.P., GRENIER D., FITTIPALDI N., SEGURA M. (2010c): *Streptococcus suis* infections in humans: what is the prognosis for Western countries? (Part II). *Clin. Microbiol. News* 32: 97-104.
- GOYETTE-DESJARDINS G., AUGER J.P., XU J., SEGURA M., GOTTSCHALK M. (2014): *Streptococcus suis*, an important pig pathogen and emerging zoonotic agent—an update on the worldwide distribution based on serotyping and sequence typing. *Emerging Microbes & Infections* 3, e45.
- HIGGINS R., GOTTSCHALK M. (2005): Streptococcal diseases. In: D’allaire, S. Mengeling, W.L., Taylor, D.J. (eds) *Diseases of Swine*. Iowa State University, IA, USA, 769-783.
- HILL J. E., GOTTSCHALK M., BROUSSEAU R., HAREL J., HEMMINGSEN S. M., GOH S. H. (2005): Biochemical analysis, cpn60 and 16S rDNA sequence data indicate that *Streptococcus suis* serotypes 32 and 34, isolated from pigs, are *Streptococcus orisratti*. *Vet. Microbiol.* 107, 63–69.
- HOA N.T., CHIEU T.T.B., NGA T.T.T., DUNG N.V., CAMPBELL J., ANH P.H., et al. (2011): Slaughterhouse pigs are a major reservoir of *Streptococcus suis* serotype 2 capable of causing human infection in southern Vietnam. *PlosOne* 6 Issue 3.

- KILPPER-BALZ R., SCHLEIFER K.H. (1987): *Streptococcus suis* sp. nov.; nom.rev. International Journal of Systematic Bacteriology 37, 160-162.
- LUN Z.R. et al. (2007): *Streptococcus suis*: an emerging zoonotic pathogen. Lancet Infect. Dis. 7:201-219.
- LUQUE I., BLUME V., BORGE C., VELA A.I., PEREA J.A., MÁRQUEZ J.M., FERNÁNDEZ-GARAYZÁBAL J.F., TARRADAS C. (2010): Genetic analysis of *Streptococcus suis* isolates recovered from diseased and healthy carrier pigs at different stages of production on a pig farm. Veterinary Journal 186, 396-398.
- MONTER FLORES J.L., HIGGINS R., D'ALLAIRE S., CHARETTE R., BOUDREAU M., GOTTSCHALK M. (1993): Distribution of the different capsular types of *Streptococcus suis* in nineteen swine nurseries. Canadian Veterinary Journal, 34, 170–171.
- NAKAYAMA T., TAKEUCHI D., AKEDA Y., OISHI K. (2011): *Streptococcus suis* infection induces to bacterial accumulation in the kidney. Microbial Pathogenesis, 87-93.
- NOPPON B., KHAENG S., SOPA A., PHUARAM P., WONGSAN R., LAOHASINNURAK T. (2014): *Streptococcus suis* serotype 2 in uncooked pork meat products in Khon Kaen, northeastern Thailand, and their antimicrobial profiles. International Journal of Scientific & Engineering Research, 5, 9, 1130-1133.
- REAMS R.Y., HARRINGTON D.D., GLICKMAN L.T., THACKER H.L., BOWERSOCK T.L. (1996): Multiple serotypes and strains of *Streptococcus suis* in naturally infected swine herds. Journal of Veterinary Diagnostic Investigation 8, 119-121.
- ROBERTSON I.D., BLACKMORE D.K. (1989): Prevalence of *Streptococcus suis* types 1 and 2 in domestic pigs in Australia and New Zealand. Veterinary Record, 124, 391-394.
- ROBERTSON I.D., BLACKMORE D.K. (1990): Experimental studies on the comparative infectivity and pathogenicity of *Streptococcus suis* type 2. II. Porcine and human isolates in laboratory animals. Epidemiology and Infection, 105, 479-484.
- ROY D., GRENIER D., SEGURA M., MATHIEU-DENONCOURT A., GOTTSCHALK M. (2016): Recruitment of factor H to the *Streptococcus suis* cell surface is multifactorial. Pathogens 5:E47. doi: 10.3390/pathogens5030047
- SALA V., COLOMBO A., GEROLA L. (1989): Infection risks of *Streptococcus suis* type 2 localizations in slaughtered swines. Arch. Vet. Italiano 40:180-184.
- STAATS J.J., FEDER I., OKWUMABUA O., CHENGAPPA M.M. (1997): *Streptococcus suis*: past and present. Veterinary Research Communications, 21, 381–407.

- SIHVONEN L., KURL D.N., ILENRICHSEN J. (1988): *Streptococcus suis* isolated from pigs in Finland. Acta Veterinaria Scandinavica 29, 9-13.
- STRANGMANN E., FROLEKE H., KOHSE K.P. (2002): Septic shock caused by *Streptococcus suis*: case report and investigation of a risk group. Int. J. Hyg. Environ. Health 205:385-392.
- STANOJKOVIĆ A., AŠANIN R., MIŠIĆ D., AŠANIN J., STANOJKOVIĆ-SEBIĆ A. (2012): The presence and serological types of *Streptococcus suis* strains isolated from pigs originating from some farms in Serbia. Fresenius Environmental Bulletin, 21, 11C, 3558-3561.
- STANOJKOVIĆ A. (2012): Investigation of presence and serotype affiliation of *Streptococcus suis* species in samples originating from pigs. PhD thesis. University of Belgrade, Faculty of Veterinary Medicine.
- STANOJKOVIĆ A., PETROVIĆ M. M., ŠKRBIĆ Z., MANDIĆ V., STANIŠIĆ N., GOGIĆ M., STANOJKOVIĆ-SEBIĆ A. (2014): Biochemical characteristics of *Streptococcus suis* strains isolated from healthy and deceased pigs. Biotechnology in Animal Husbandry 30, 4, 699-704.
- STANOJKOVIC A., PETROVIC M.M., STANIŠIĆ N., DELIC N., MANDIC V., PETRICEVIC M., PETRICEVIC V., STANOJKOVIC-SEBIC A. (2015): *Streptococcus suis*, most common serotypes isolated from diseased piglets in some farms in Serbia. 4th International Congress New Perspectives and Challenges of Sustainable Livestock Production, Belgrade, Serbia, October 7 – 9, 2015, Proceedings, 336-343.
- STANOJKOVIC A., OSTOJIC-ANDRIC D., PETROVIC M., STANISIC N., GOGIC M., STANOJKOVIC-SEBIC A., RADOVIC C. (2016): Prevalence of *Streptococcus suis* serotype 2 strains isolated from major parts of fresh pork meat. The International Conference of the University of Agronomic Sciences and Veterinary Medicine of Bucharest Agriculture for Life, Life for Agriculture, Series C. Veterinary Medicine, Vol. LXII, Issue 2.
- TANG J. et al. (2006): Streptococcal toxic shock syndrome caused by *Streptococcus suis* serotype 2. PLoS Med. 3:151.
- TIEN H. T., NISHIBORI T., NISHITANI Y., NOMOTO R., OSAWA R. (2013): Reappraisal of the taxonomy of *Streptococcus suis* serotypes 20, 22, 26, and 33 based on DNA–DNA homology and *sodA* and *recN* phylogenies. Vet. Microbiol. 162, 842–849.
- VÖTSCH D., WILLENBORG M., WELDEAREGAY Y.B., VALENTIN-WEIGAND P. (2018): *Streptococcus suis* - The "Two Faces" of a Pathobiont in the Porcine Respiratory Tract. Front Microbiol. 2018 Mar 15, 9:480. doi: 10.3389/fmicb.2018.00480.

- WANG Y., ZHANG W., WU Z., LU, C. (2011a): Reduced virulence is an important characteristic of biofilm infection of *Streptococcus suis*. *FEMS Microbiol. Lett.* 316, 36–43. doi: 10.1111/j.1574-6968.2010.02189.x
- WERTHEIM H.F., NGUYEN H.N., TAYLOR W., LIEN T.T., NGO H.T. (2009): *Streptococcus suis*, an important cause of adult bacterial meningitis in northern Vietnam. *PLoS One* 4: e5973.
- WILLENBORG J., FULDE M., DE GREEFF A., ROHDE M., SMITH H. E., VALENTIN-WEIGAND P., et al. (2011): Role of glucose and CcpA in capsule expression and virulence of *Streptococcus suis*. *Microbiology* 157, 1823–1833. doi: 10.1099/mic. 0.046417-0
- WILLIAMS A.E., BLAKEMORE W.F., ALEXANDER T.J.L. (1988): A murine model of *Streptococcus suis* type 2 meningitis in pigs. *Research in Veterinary Science*, 45, 394-399.

=====
CIP - Каталогизacija у публикацији Народна библиотека Србије,
Београд

636/638(082)(0.034.2)

631/635(082)(0.034.2)

**INTERNATIONAL Symposium Modern Trends in Livestock Production
(14**

; 2023 ; Beograd)

Proceedings [Elektronski izvor] / 14th International Symposium Modern
Trends

in Livestock Production, 4-6 October 2023, Belgrade, Serbia ; [organizer]
Institute

for Animal Husbandry, Belgrade - Zemun ; [editor Zdenka Škrbić]. -
Belgrade :

Institute for Animal Husbandry, 2023 (Belgrade : Institute for Animal
Husbandry).

- 1 USB fleš memorija ; 1 x 3 x 6 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. -
Tiraž 100.

- Bibliografija uz svaki rad.

ISBN 978-86-82431-80-0

a) Сточарство -- Зборници b) Пољопривреда -- Зборници

COBISS.SR-ID 125636361

=====



14th INTERNATIONAL SYMPOSIUM
MODERN TRENDS IN LIVESTOCK PRODUCTION

4 - 6 October 2023 - Belgrade, Serbia

PROCEEDINGS

INSTITUTE FOR ANIMAL HUSBANDRY

Autoput 16, P. Box 23, 11080, Belgrade - Zemun, Serbia

www.istocan.bg.ac.rs

ISBN 978-86-82431-80-0

