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SLOVAK RESEARCH AND DEVELOPMENT AGENCY

MINISTRY OF EDUCATION, SCIENCE, RESEARCH AND SPORT OF THE SLOVAK REPUBLIC

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2022 EXCELLENCE IN SCIENCE

Published in 2022

EXCELLENCE IN SCIENCE

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FOREWORD

Dear friends,
we feel honoured to invite you to read the sixth publication The Excellence in Science by which the Agency presents the implementation of projects achieving outstanding level. The publication should meet the needs of everybody who is interested in finding more information on research support in Slovakia.

The publication informs about the implementation and results of several years lasting work of Slovak experts on projects from 2017 up to 2021 in the basic and applied research of natural, technical medical, agricultural, social sciences and humanities. Of course, the publication and its content cannot compete with the electronic sources of latest information that are much faster and updated. However, it definitely has certain positives, it enabled us to sum up all the activities conducted by project teams and co-operating institutions within a scientific community in Slovakia. As we have already published the sixth publication, we believe it can clearly present the progress achieved in particular fields of science in which the projects presented in this publication ware implemented.

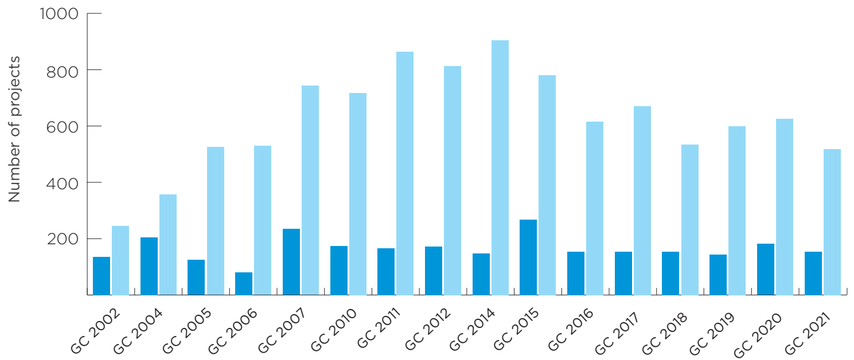
Since its establishment the Slovak Research and Development Agency has been a significant part of the state aid for basic and applied research and development in Slovakia. We are very pleased by the fact you can hardly find anyone from research and development that does not know the name of our Agency. However, it remains our goal to improve every year and support more projects that end up at an excellent level of solution.

Finally, our deepest thank you belongs to all solvers of the projects presented in the publication as well as to those who contributed to the preparation of the sixth publication of the research projects with excellent level 2022.

JUDr. Stanislav Mydlo
Director

Dr. Ing. Robert Mistrík
Chairperson

INTRODUCTION



Summary of applications submitted and supported projects in the general calls in the years 2002 – 2021

Supported projects

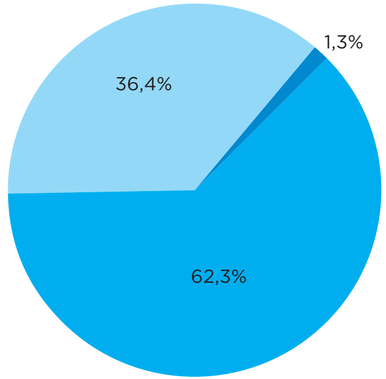
Submitted applications

Department of Science and Technology	Registered applications	Financed projects	Success Rate (%)
Natural sciences	142	39	27,5%
Technical sciences	184	43	23,4%
Medical sciences	56	13	23,2%
Agricultural sciences	79	19	24,1%
Social sciences	116	29	25,0%
Humanities	38	11	28,9%
Total	615	154	25,0%

Success rate of applications supported by GC 2016 as per scientific departments.

The projects presented in this publication have been submitted within the general call to the Slovak Research and Development Agency marked GC 2016. General Call GC 2016 had no limitations on the substantive focus of the projects. Specific focus, objectives and contents of the research and development were determined by the applicants themselves. Applications could be submitted by legal entities as well as natural persons – entrepreneurs without limitation as per sector of research and development. 615 applications for funding were received and registered as part of the general call GC 2016, in order to resolve research and development projects and 154 applications were supported. Start of the project solution was 1. 7. 2017. Latest date of completion of project solutions was 31. 12. 2021. In 2022 subsequently completed projects were evaluated by different scientific councils on the basis of the final reports on projects submitted by the principal investigator within 30 days of the end of solution.

In this publication the Slovak Research and Development Agency presents the selection of the most successful completed and subsequently evaluated projects from the general call GC 2016 in all sectors of Slovak science and technology.

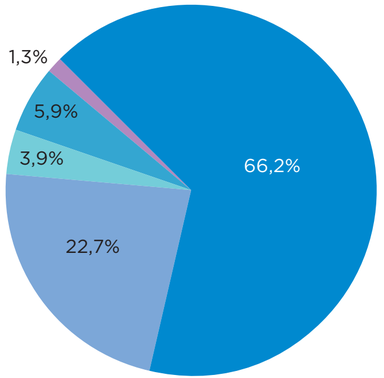


Basic Research / 96 projects

Applied Research / 56 projects

Development / 2 projects

Percentage rate of projects supported as per the nature of the research



Universities / 102 projects

SAS / 35 projects

State (SAS excluding) / 6 projects

Business / 9 projects

Non-profit / 2 projects

Breakdown of funded projects as per sector

NATURAL SCIENCES

Sintered biodegradable metallic materials

Principal investigator
prof. RNDr. Renáta Oriňaková, DrSc.
Applicant organisation
Pavol Jozef Šafárik University in Košice
Participating organisation
Institute of Materials Research
Term of solution
7/2016 — 12/2020
Budget from agency
210 000 €
Project ID
APVV-16-0029

Research subject

The APVV-16-0029 project focused mainly on basic research of biodegradable materials prepared from powdered metals. It is a relatively new class of materials that represent an interesting alternative to currently used inert orthopedic implants. Degradable biomaterials gradually corrode *in vivo* during the remodelation of new bone tissue. They degrade through corrosion processes and after fulfilling their function they do not need to be removed from the body by secondary surgery.

Aim of the research

The main goals of the APVV-16-0029 were to

- master the preparation of suitable starting powders and the production of final products with a defined composition, structure, and surface properties
- study the influence of various coatings and surface modifications on the corrosion properties, mechanical properties, and biocompatibility of the material
- identification of parameters that determine how fast the material corrodes and detection of changes in these parameters during corrosion
- find out whether, how, and to what extent the mechanical properties of the material depend on the parameters controlling corrosion
- understand the cause and dynamics of changes in the mechanical properties of the material with an increasing degree of degradation caused by corrosion

Achieved results

During the years 2016 – 2018, efforts were focused on the preparation of compact biomaterials by sintering metallic powders and the preparation of foam-like biomaterials by the replication method with polymeric (PEG, PLA) and bioceramic (HAp) coatings. In this phase of the project, the influence of various physical and chemical parameters of powder materials preparation (powder mixture composition, sintering method, temperature, and sintering method) and surface treatment of sintered materials (polymer coating, bioceramic coating) on the resulting properties of compact and foam-like iron-based materials were studied. Data on microstructure, mechanical properties (tensile strength, flexural strength, Young's modulus of elasticity), corrosion resistance in Hank's solution, and cytotoxicity of sintered compact, foam-like, and cellular materials were also obtained. In the years 2019 - 2020, we have prepared Fe materials by sintering hollow particles. We have also worked on the preparation of Fe foam-like biomaterials with a suitable surface modification to increase the corrosion rate and improve mechanical properties and biocompatibility. We have also developed the mathematical models of corrosion processes to be able to theoretically predict the degradation properties of metals in the future. Thanks to the study of the mechanical properties of foam-like samples, we understood the dynamics of changes in the mechanical properties of the material with progressive degradation and evaluated the effect of the polymer coatings. The results obtained during the project have so far been published in 23 peer-reviewed CC journals, 12 papers have been published in peer-reviewed scientific journals abroad, 3 in journals in the Slovak Republic and together they have reached 98 citations.

Benefits for practise

We have gained a valuable experience in the preparation of degradable materials during the project implementation period. At the same time, we have gained important knowledge about the influence of physical parameters on the resulting properties of these materials (mechanical, degradation as well as biological), which can be continuously modified and optimized to achieve "tailor-made" biomaterial. This biomaterial could become a suitable degradable implant soon. To achieve this goal, it is necessary to perform *in vivo* tests on animal models, on which we are currently working.

Fig. 1. / Schematic illustration of differences in corrosion properties of sintered materials: bare Fe in air (a), Fe+PEI in air (b), Fe in Hanks' solution (c), Fe+PEI in Hanks' solution (d), Fe in Hanks' solution with BSA (e), and Fe+PEI in Hanks' solution with BSA (f) (PEI – polyethyleneimine, BSA – bovine serum albumin).

Fig. 2. / Representative images of Fe (a), Fe-PEI1 (b), Fe-PEI3 (c), and stainless steel (d) surfaces treated with the fluorescently stained human adult dermal fibroblast cells. Detailed images of the cell morphology on the iron foam surface (e) and SS surface (f) are also depicted. Changes in pH of sample extracts after 4 and 24h of incubation at 37 °C (g). Cell growth curves (h).

Fig. 3. / SEM micrograph of the Fe-PEI1 (a), Fe-PEI2 (b), and Fe-PEI3 (c) cross-sections with arrows marking the PEI layer. Representative SEM micrographs of coated iron foam (d,e) with EDX analysis of thick and thin layer incidence areas (f,g).

Fig. 4. / Nyquist (a,b) and Bode (c,d) plots of samples (Fe, Fe-PEI) before and after 60 min of corrosion.

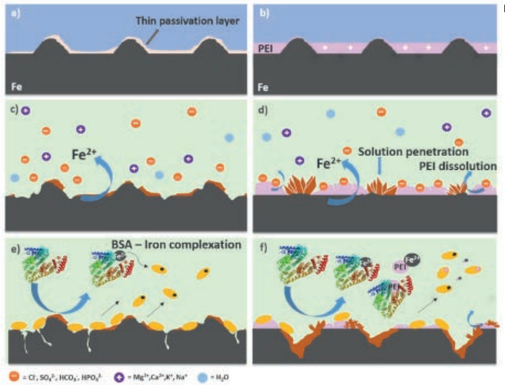


Fig. 1

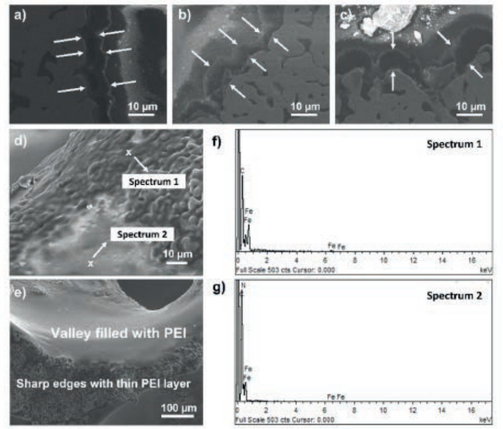


Fig. 3

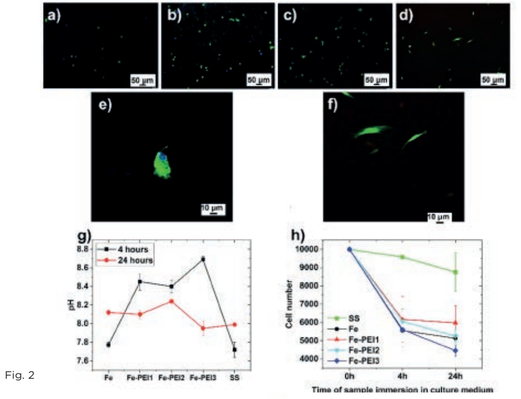


Fig. 2

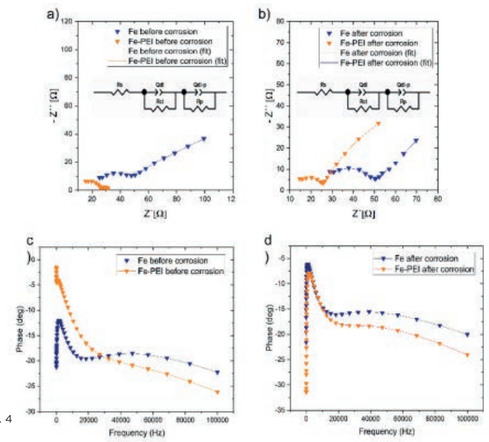


Fig. 4

Aggregation of transition metals in living organisms

Principal investigator
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Term of solution
7/2017 — 6/2021
Budget from agency
210 000 €
Project ID
APVV-16-0039

Research subject

Knowledge about the role of the transition metals with focus to the deposits of iron oxides existing in various organs of living organisms represent the scope of the project. Nanoparticles, thought as pathological forms without any positive functionality are investigated in detail.

Aim of the research

The project is based upon identification, quantification and evaluation of properties of mineral, non-physiological forms of iron that exist in the human brain and spleen in the form of iron oxides. For this purpose, the samples extracted post *mortem* from the Globus Pallidus and from spleen of healthy and also ill individuals (in the accredited laboratory using all ethical norms) were investigated; they after extraction have been lyophilized. Physical methods of investigation cover the optical microscopy, electron microscopy in SEM and TEM modes, Mössbauer spectroscopy (gamma resonance) and mostly the SQUID magnetometry by measuring the magnetic susceptibility, magnetization in the zero field cooling mode (ZFCM) and field cooling mode (FCM), remnant magnetization, coercive field, and the complete hysteresis loop at various temperatures.

Achieved results

For samples extracted from the human brain the electron spectroscopy in the SEM and TEM bring figures of deposits whose sizes vary between nano- to micrometres (Fig. 1).
The Mössbauer spectroscopy confirmed that the deposit of iron oxides are formed mostly of non-magnetic hematite (γ-Fe2O3) and magnetic maghemite (α-Fe2O3) along with the ferromagnetic magnetite (Fe3O4). A set of parameters that characterize the magnetic properties of samples has been obtained by the SQUIT magnetometry. These parameters were mutually correlated using modern multivariety statistical methods, such as the cluster analysis and the principal component analysis (PCA) – Fig. 2. (There are no medical records about disfunction of iron metabolism for these 20 donors.) As a result, only the Curie constant (C) and the remnant magnetization (RM2, RM4) clearly correlate with the age of the donor.

The samples extracted from the human brain were classified into three classes according to their magnetoactivity: I – prevailing diamagnetism, III – prevailing para- or ferromagnetism, II – intermediate behaviour. For all '') samples a magnetic hysteresis at low temperature has been observed; for some samples this survives even until room temperature which is a fingerprint of the ferromagnetic magnetite or maghemite. In one sample Verwey phase transition has unambiguously be observed which confirms presence of the magnetite (a hard magnet) – Fig. 3.
The formation of the above mentioned pathological deposits has been modelled by reduction of the iron salts using a set of native aminoacids and monoamines; for this purpose, voltammetry and quantum-chemical ab initio calculations were used. Alpha-aminoacids (glycine, alanine, asparagine, cysteine, arginine, glutamate, phenylalanine, tyrosine, triptophane, histidine) and monoaminergic neurotransmitters (dopamine, noradrenaline, adrenaline) reduce the Fe(II) salts in the anaerobic conditions to colloidal Fe(0) that on exposing to air is readily oxidized to a set of Fe(II)/Fe(III) oxides. Those aminoacids also interfere with the native ferritin.

Benefits for practise

The project belongs to the basic research with the output to the general human knowledge. Its unique feature is that it integrates skills of physics, chemistry, spectroscopy, biology, medicine, quantum chemical calculations and modern statistical techniques.

Key publications

L. Dlháň, M. Kopáni, R. Boča: *Polyhedron* 157 (2019) 505. Magnetic Properties of Iron Oxides Present in the Human Brain.
H. Svobodová, J. Hlinková, P. Janega, et al. *Open Physics* 17 (2019) 291. Deposits of iron oxides in the human globus pallidus.
L. Dlháň, R. Krylov, M. Kopáni, R. Boča: *Nova Biotechnol. Chim.* 18 (2019) 52. Magnetic response of bovine spleen.
H. Svobodová, D. Kosnáč, H. Tanila, et al. *Biometals* 33 (2020) 1. Iron–oxide minerals in the human tissues.
M. Kopáni, J. Hlinková, H. Ehrlich, D. Valigura, R. Boča, *J. Bioanalysis and Biometals* 9 (2017) 80. Magnetic properties of iron oxides in the human globus pallidus.
A.P. Petrenko, P. Summers, S. Simon, et al. *Science Advances* 5 (2019) eaax2805. Extreme biomimetics: Preservation of molecular detail in centimeter-scale samples of biological meshes laid down by sponges. Impact Factor 13.5.

Fig. 1 / SEM and TEM records of electron microscopy for a sample from the human brain extracted from Globus Pallidus. After indexing, the diffraction patterns identify the presence of hematite. Scale bar – 1 μm.

Fig. 2 / Biplot of the PCA method: Filled circles – samples, rays – positions of magnetic parameters.

Fig. 3 / Temperature dependence of the magnetization for the sample No. 20 confirming the Verwey phase transition in the magnetite Fe_3O_4 at T_V = 120 K.

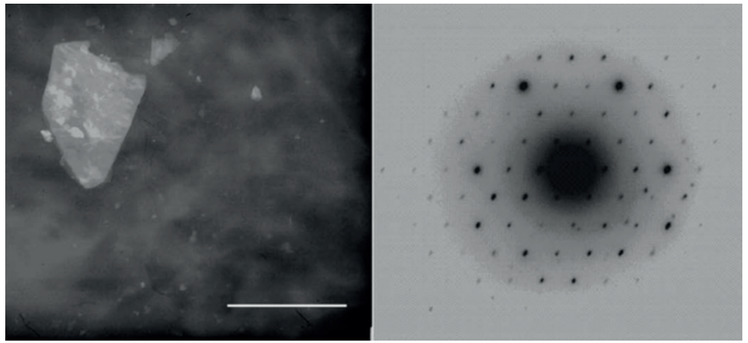

Fig. 1

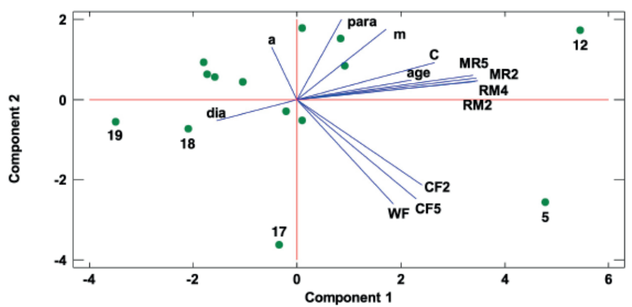

Fig. 2

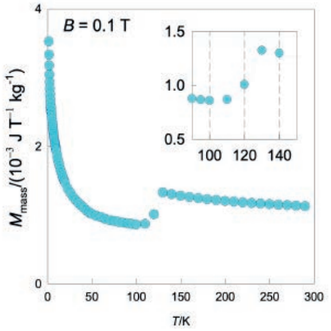

Fig. 3

Probabilistic, algebraic, and quantum mechanical aspects of uncertainty

Principal investigator
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Slovak Academy of Sciences, Bratislava
Participating organisation
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Faculty of Civil Engineering, Bratislava
Term of solution
7/2017 — 6/2021
Budget from agency
143 674 €
Project ID
APVV-16-0073

Research subject

Uncertainty accompanies us throughout the whole of mankind's history and, therefore, people ever before tried to recognize the uncertainty, what it expects them, how it can be estimated, and what is necessary to do to minimize the negative effect of uncertainty. Appearing quantum mechanics, it was realized that uncertainty is playing a fundamental role in measuring quantum-mechanical quantities and it can be nowadays studied by advanced mathematical methods.

Aim of the research

Using the latest methods of quantum structures we studied the mathematical foundations of quantum mechanics and of quantum measurements. We deepened our knowledge about partial and total algebras like effect algebras, MV-algebras, synaptic algebras, orthomodular lattices, BL-algebras, residuated lattices, and their non-commutative generalizations and states on them with respect to partially ordered groups. Methods of the theory of categories clarify specific properties of quantum structures. Aggregation methods were used to combine selected values of measurements into one aggregation function. Uncertainty contained in quantum measurements was analyzed from the point of view of states, and quantum channels, and it was aimed at quantum mechanics, quantum information theory, and the description of measures of noncompatibilities.

Achieved results

The theory of MV-algebras, as a many-valued generalization of Boolean algebra, have applications in the last decades in many areas of research, and therefore, they are often generalized. We have presented EMV-algebras where a top element is not assumed a priori, and we have also given its non-commutative generalization – pseudo EMV-algebras. We generalized the Loomis—Sikorski theorem for a representation of σ-complete EMV-algebra by an EMV-tribe of fuzzy sets. We have proved the Cantor—Bernstein theorem of locally σ-complete EMV-algebras and σ-complete algebras, and we have characterized free EMV-algebras. We showed a relationship between state-morphisms, which are extremal states, and the existence of maximal and normal states for pseudo MV-algebras. We presented an integral representation of states by σ-additive classical probability measures defined on the space of extremal states. These algebras have uncountably many classes similar to varieties, whereas EMV-algebras have only countably many. Since EMV-algebras/pseudo EMV-algebras are not varieties, we have presented weak EMV-algebras and weak pseudo EMV-algebras as the least variety containing all EMV-algebra and pseudo EMV-algebras, respectively.

Basic notions in the theory of quantum structures are a state, an analogy of probability, an observable, an analogy of measurable functions, and a kind of a σ-homomorphism from the Borel sets into a quantum structure. We get a spectral resolution if we focus on infinite intervals of type $(-\infty, t)$ for each real number t. There is an essential question of when the information from the spectral resolution can be extended to an observable. In a series of papers, this question was studied for different dimensions and different classes of quantum structures like monotone σ-complete complete effect algebras with RDP or MV-algebras. In the infinitary variety of σ-complete Riesz MV-algebras, we introduced an algebraic analogy of random variable as a homomorphism defined on a free algebra in RMVσ. This was used to describe stochastic processes in a non-classical Lukasiewicz logic, and we defined stochastic independence.

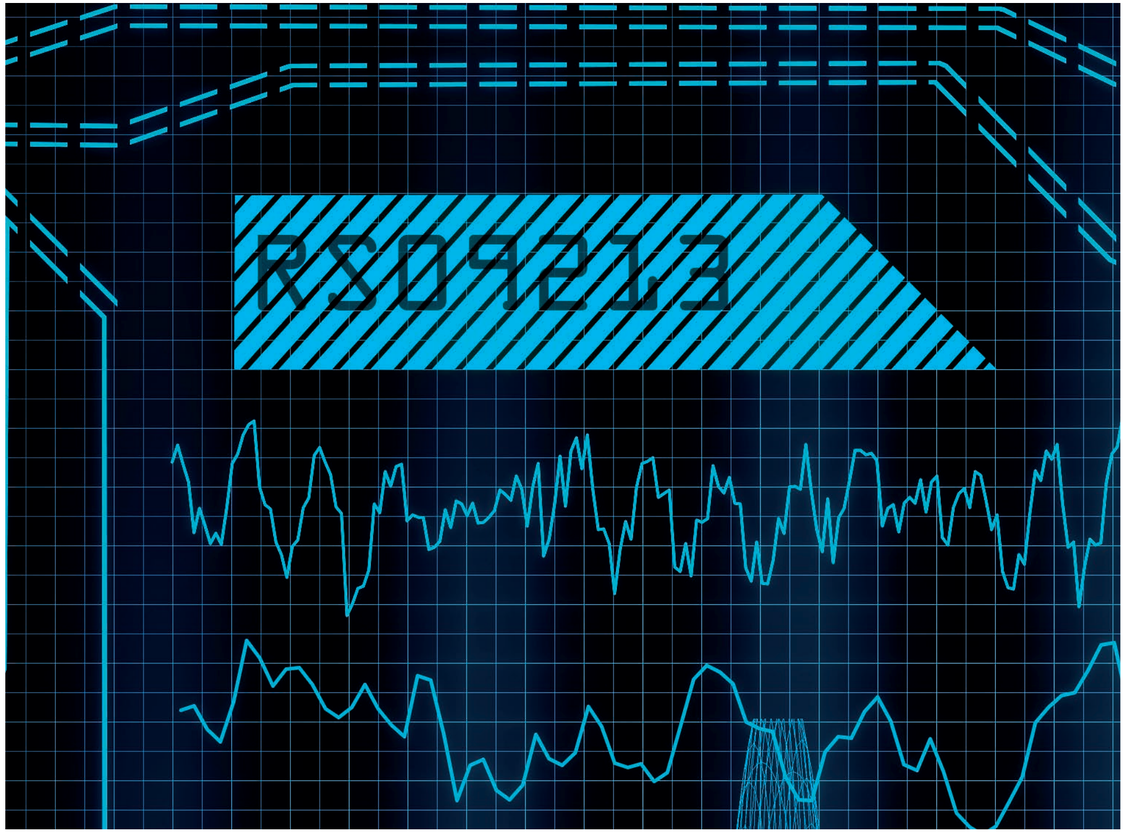
Another important class of quantum structures is the class of synaptic algebras. It is well-known that events in the effect algebra of a Hilbert space form a lattice with respect to the spectral resolution introduced by Olson. This ordering was also introduced for synaptic algebras, and it is established that the corresponding effect algebra becomes a Dedekind σ-complete lattice. We found necessary and sufficient conditions when a synaptic algebra is norm-complete, and the Kadison antilattice theorem for synaptic algebras was proved, i.e. two elements have a join if and only if the elements are comparable. We also studied a relationship between synaptic algebras and so-called generalized Hermitian algebra and fuzzy observable and sharp observables. A significant result concerns a description of two notions of observables.

Dimension effect algebras are unit intervals in dimension groups. We proved that the effect-algebraic product of dimension effect algebras is again a dimension effect algebra. The compatibility of quantum channels is important in the generalized theory of probability concerning the Bell non-locality. We found general conditions for compatibility. We studied channels on atomic von Neumann algebras with a fixed faithful state. We described the so-called decoherence-free subalgebra and periodic behavior on it. It is proved that this subalgebra is a region of values of a conditional mean value, and therefore, it is always atomic. We also studied a conditional probability and stochastic dependence for events modeled by a Lukasiewicz tribe of all measurable functions. The study is based on properties of joint experiments and quantum channels that are equivalent to Markov kernels. We gained exciting results on sandwich Rényi relative α-entropies for normal states on a von Neumann algebra.

An essential question for the study of uncertainty is its aggregation possibility of some similar data. We started to study this problem using lattices. Basic notions are t-norms, t-conorms, and uninorms and idempotent n-uninorms. We characterized all functions which can be constructed by the z-ordinal sum of semigroups derived from continuous t-norms, t-conorms, representable uninorms and idempotent semigroups. It was shown that this class of functions is bigger than the class of n-uninorms with continuous associated functions, and every n-uninorm has n characterizing multi-functions.

Benefits for practise

We gained results that can be useful in the handling of quantum information.



Modern amorphous and polycrystalline functional materials for sensors and actuators

Principal investigator
prof. RNDr. Rastislav Varga, DrSc.
Applicant organisation
University of Pavol Jozef Safarik in Košice
Participating organisations
University of Presov
Technical University of Košice
Slovak University of Technology in Bratislava
Term of solution
7/2017 — 12/2021
Budget from agency
230 000 €
Project ID
APVV-16-0079

Research subject

At present, industrial, medical and IT technology developments lead to the demand for the miniaturization of sensors and actuators, which should be characterized by increased sensitivity while maintaining the most diminutive possible dimensions. In the case of robotics with a requirement for motion sensors; pressure in the robotic arm, temperature; etc., medicine with a need for miniature temperature and pressure sensors, or the Internet of Things, where several positions, temperature, and pressure sensors are required to ensure monitoring of the most significant number of objects. Currently used sensors cannot handle these requirements (due to their dimensions, sensitivity, consumption, etc.). That is why the development of new materials with outstanding physical properties, which will be able to meet the requirements of modern times due to their dimensions, sensitivity, consumption and produced quantity, is highly relevant.
The research focused on the development of new materials for miniature sensors and actuators, with unique physical properties. By their suitable in one material, it is possible to create multifunctional sensors as well as miniature actuators, which are themselves sensors.

Aim of the research

The project's main aim is to understand the influence of various parameters (chemical composition, magnetic anisotropies, heat treatment, etc.) on selected physical phenomena in thin magnetic microwires, in order to increase the efficiency of magnetocaloric and shape memory phenomenon, which could benefit their use in the construction of miniature sensors and actuators.

Achieved results

New functional materials have been developed and characterized by exceptional physical properties for use in sensors and actuators. By combining the nanocrystalline structure with the onset of a superparamagnetic phenomenon, we achieved a high sensitivity of the critical field to the temperature in the range of human body temperatures, which was used for the temperature measurement inside the skull through a titanium implant. We used microwires with high magnetostriction based on FeSiBP for measuring the deformation of wooden plywood and modelling the detection of osteomalacy in animal bones.
We have developed a new class of Ni-Fe-Ga-based glass-coated Heusler microwires characterized by the magnetocaloric effect. We have shown that the microwire based on $Ni_{54}Fe_{19}Ga_{27}$ is characterized by a twice higher magnetocaloric effect in the region of room temperatures due to the fact that the structural transformation and the Curie temperature overlap. The specific shape of the thin wire, together with the shape anisotropy and the specific structure of the martensitic phase, lead to a change in the direction of easy magnetization during the structural transformation and thus to a huge change (>1200%) in the initial permeability. This can be used for accurate temperature measurement and the construction of SMART temperature actuators, which can change and measure the temperature. The shape of the wire, together with a relatively small saturation field, enables an increase in the efficiency of the magnetocaloric effect in low fields, which is particularly advantageous in practical applications.
Selected microwires Ni-Mn-X, Ni-Fe-X, Fe-Mn-X (X=semimetal) are characterized by a structural transformation associated with a change in lattice parameters, which makes them suitable for applications in miniature position or extension actuators. In some cases, it is possible to prepare a microwire that shows a monocrystalline structure along its length. Such wires are then characterized by a large change in dimensions (4%) during the structural transition without the need for additional heat treatment or training. The direction of the easy magnetization axis and the initial permeability change together with the change of the structure. Therefore, detecting the phase and thus the elongation in SMART miniature actuators is possible.

Benefits for practise

The project's results can be applied (and are already applied) in the development of modern miniature contactless sensors of temperature, pressure, torsion, magnetic field, position, and in the development of miniature actuators for the position, extension, temperature, etc. By suitably combining the shape of the material with the magnetocaloric or the shape memory effect, it is possible to develop miniature SMART actuators with sensing capabilities.

Fig. 1 / The focus of the project was to study glass-coated microwires (top left), which can be used as mechanical actuators for robotic hands (top right), as well as Heusler nanowires prepared by electrodeposition (bottom right), suitable for spintronic devices. As part of the project, the spin polarisation measurement methodology (based on the Andreev reflection method) was modified for the nanowire level.

Fig. 2 / NiFeGa-based glass-coated Heusler microwires are characterized by 2% elongation due to temperature increase. At the same time, the magnetic permeability changes up to 1600 times. The presented effect enables the construction of SMART miniature actuators with sensory capabilities.

Fig. 3 / Heusler nanowires based on NiFeGa are characterized by a Magnetically induced shape memory effect. The magnetic field required for the shape change decreases with temperature. The presented effect enables the construction of contactless nanoactuators.

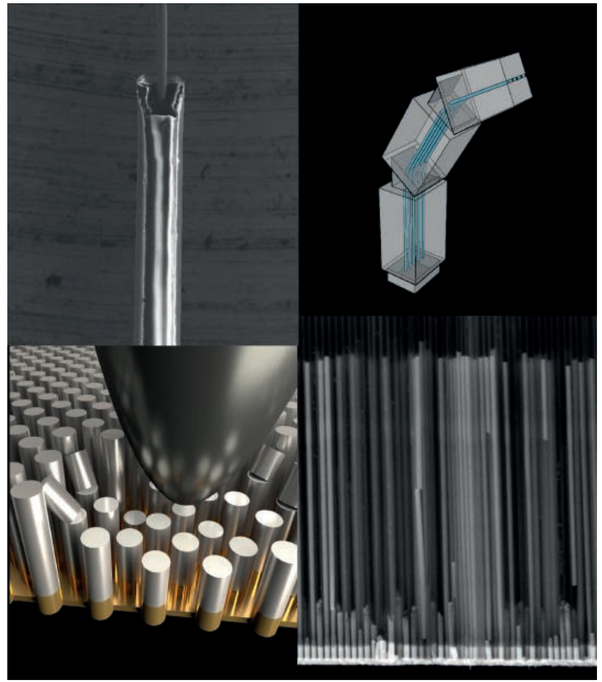


Fig. 1

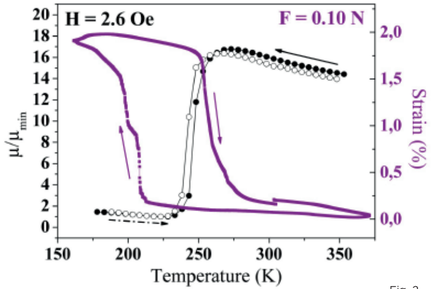


Fig. 2

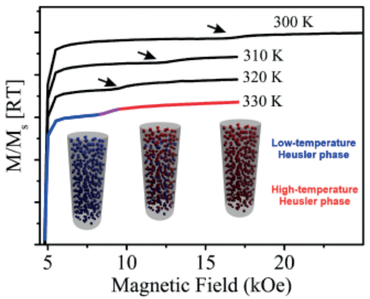


Fig. 3

Geodynamics of the Alpine–Carpathian junction constrained by dating of the Cenozoic evolutionary phases in the Vienna and Danube basins

Principal investigator
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Faculty of Natural Sciences
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Term of solution
7/2017 — 12/2021
Budget from agency
225 000 €
Project ID
APVV-16-0121

Research subject

Geological time is a key factor for understanding the evolution and development of the planet Earth. Therefore, dating of the rock complexes and related tectonic events is indispensable. The study area spreading on the Eastern Alpine and Western Carpathian junction is represented beside mountain ranges of the Leitha and Malé Karpaty Mts. also by the Vienna and Danube basins. Their sedimentary fill and the pre-Neogene basement create an excellent archive yielding data about the duration and character of evolutionary stages and geodynamics of the area. When index fossils are present, the biostratigraphy is the most common dating tool for the sedimentary rocks. When barren, geochronological and radiometric dating tools are used. In the last decade some new techniques were discovered and some were largely improved, e.g. cosmogenic nuclide dating and thermochronology method. The dating results can be used for dating of the tectono-sedimentary development. This exact data help to create a new geodymanic evolution model of the area during the Cenozoic period. Despite the fact, that such model was presented in several studies in the past, it is still very actual to refine the time span of tectonic events. It is essential both for the improvement of geological knowledge and also for the geohazard (seismic) assessment especially in a region which possesses dense urban agglomerations, numerous gas storages, nuclear and hydroelectric power plant. For further geophysical research and predictions in this issue, only well-defined time sequencing can bring a substantial base of the tectonic activities during geodynamic evolution of the region. Important fact is that all obtained valuable geochronological data remain available for future geological research and interpretation.

Aim of the research

Are to use a wide variety of sediment and crystalline rock dating. Such data together with modern biostratigraphy of planktonic organisms will provide opportunity to correlate the Neogene and Quaternary regional time scale with the standard European stratigraphic scale. Synthesis of dating results, creation of time correlation levels and their implementation into the innovated - Model of the geodynamic evolution of the Alpine-Carpathian junction, will enable an exact definition of tectonic processes time span.

Achieved results a Benefits for practise

Namely modified structural-tectonic model of the development of the Alpine-Carpathians junction area, coupled with the lithostratigraphic model of the Vienna and Danube basins, including the implementation of newly acquired age data (*time correlation levels*) were met. The obtained geochronological data will be used for the geodynamic interpretations in the modern model of the basins sedimentary fill, but also in practice of identification of geohazards. The ^{40}Ar / ^{39}Ar geochronological data can be considered as one of the most important results of the research. Such accurate information serves to determine the exact age of the geodynamic events in the Cenozoic. The correlation of radioisotope dating with biostratigraphy of the basin sedimentary record was of great importance for understanding the paleogeographic changes even in the scope of the broader area of the Central Europe. The solving of the project issues also significantly stimulated the application of a new dating method based on the ratio of authigentic $^{10}Be/^{9}Be$, which significantly contributed to the definition of individual stages of the Upper Miocene development of the Pannonian basin system. In situ produced cosmogenic nuclides ^{10}Be and ^{26}Al enable exact dating of the Pliocene-Quaternary evolution. Besides highly ranked publications in currented journals, as evidenced by citations recorded in databases, an important result of the project were activities that helped to educate a new generation of scientists (graduates, doctoral and post-doctoral students). It was the mastering of up-to-date methods and the issue of exact dating that led to the personal professional growth of young researchers (junior) - colleagues who established themselves in science during the project, expanded their international contacts and formed their own idea of how to deal with future tasks. This was exceptionally important for their personal growth, as evidenced by the new proposed projects with a similarly focused aims as the project APVV-16-0121 (projects APVV-20-0120 and VEGA 1/0526/21).

Fig. 1 / Radiometric dating of sediments based on the cosmogenic nuclide ratio 10Be/9Be integrated with paleontological analyzes (Bratislava, Mlynská Dolina site) allowed to establish the age of Lake Pannon transgression on the Malé Karpaty Mts., situated between the Vienna and Danube basins (Šujan et al., 2021).

Fig. 2 / Neogene geodynamic processes and tectonics in between the African and European lithospheric plates led to formation of the Alpine, Carpathian and Dinaride mountain ranges. Neighbouring depressions were flooded by the Central Paratethys Sea. The closure of the marine gateway towards the Mediterannean Sea caused the origin of Lake Pannon, and later formation of the extensive flatlands behind the mountain arcs (Kováč et al., 2017, 2018).

Fig. 3 / A seismoactive zone is located on the eastern margin of the Vienna Basin. Wedge-shaped deformations appear in the wind-blown dune sands in the Vienna Basin, deposited during the last glacial. Dating of these structures implied recurrence periods of earthquakes to ca. 100 years (Šujan et al., 2022).

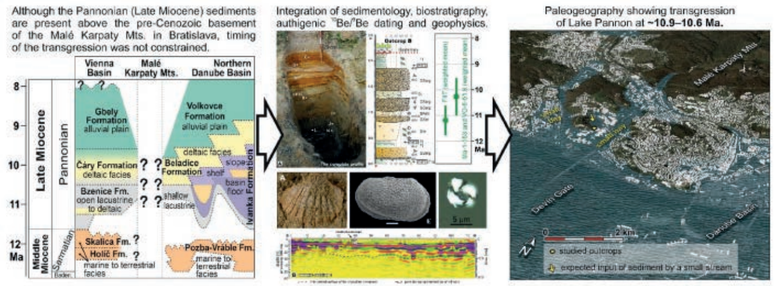


Fig. 1

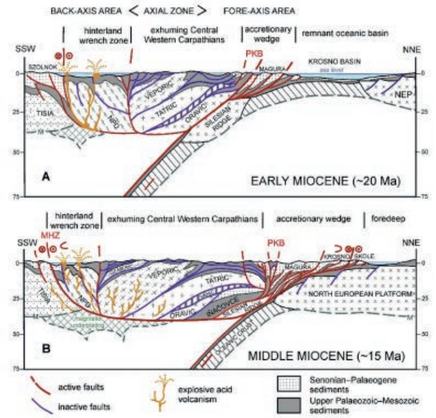
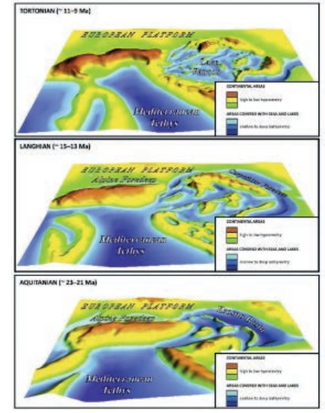


Fig. 2



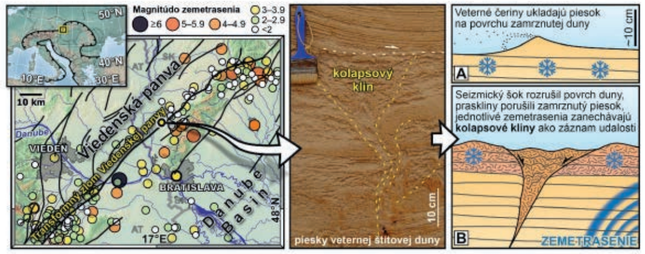


Fig. 3

Multidisciplinary research of geophysical and structural parameters, and environmental impacts of faults of the Western Carpathians

Principal investigator
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Participating organisation
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Term of solution
7/2017 — 12/2021
Budget from agency
225 000 €
Project ID
APVV-16-0146

Research subject

The geological structure of the Western Carpathians is disturbed by the faults which, especially in the late stages of the development of the Carpathians, played a significant role as dynamic block interfaces. The subject of the research was known map faults, which have a direct impact on the local geological structure, but also on the socioeconomic sphere and the environment. Data on the faults and their parameters are therefore valuable information both for basic geological research and for territorial planning, construction activities and assessment of health and natural risks arising from the geological environment. The project was aimed at identifying the course and parameters of selected faults based on a multidisciplinary approach of applying geoscientific and geodetic methods. From the known tectonic faults of the Western Carpathians, the following faults were selected for detailed research: Vikartovce, Sološnica and Zázriva.

Aim of the research

The aim of the project was to apply current geophysical, geological, and geodetic methods to detect the faults, map their course and determine their parameters. The ambition of the project was to develop an optimized methodology for the most effective way of detecting the fault parameters through own field observations, measurements, and testing, especially of geophysical methods. For the first time, the recent movement activity of a specific fault was monitored by high-precision measurements of gravity values and satellite radar interferometry.

Achieved results

By testing field methods, an optimized procedure was created, how and with what methods to effectively determine the parameters and properties of mapped faults. The knowledge was processed in a sample study of the Vikartovce fault, in which all relevant methods were used, including a four-year geodetic monitoring of the tendencies of recent movements. It was found that the Vikartovce fault is a steep north-tilted strike. It was rotated to today's steep position by tilting blocks. From the point of view of Neotectonic activity, it turns out to be a very interesting area of the Štrba threshold and Poprad Basin, which shows a slight uplift tendency. The analysis of the geodetic data points to horizontal movement activity in the N to NE direction. Emphasis was also placed on the environmental aspect of fractures, which affects the quality of life and the impact on human health. Therefore, in addition to soil Rn emanometry, Rn activity was also monitored in the homes of three villages (Sološnica, Vydrník, Zázrivá) situated on fault lines. The results showed that environmental research can provide valuable indications of the presence of faults in built-up areas, and possible findings of exceeding limit values will enable the implementation of corrective measures. Recent fault activity was also identified by seismic monitoring and methods of engineering geology. A research trip to the central part of the Himalayas in Nepal for the purpose of comparative studies of the structure and fault tectonics of two segments of the Alpid orogen (Carpathians vs. Himalayas) brought fruit in the form of experience from a geologically perfectly exposed super mountain range and the perspective of cooperation with Himalayan geologists. The expedition started an informal collaboration between Faculty of Natural Sciences, Comenius University, Bratislava and Earth Science of the Slovak Academy of Sciences, Bratislava with Tribhuvan University in Kathmandu. The results of the research carried out within the project have so far been published by the researchers in 33 current publications, 53 publications of other categories and 3 monographs.

Benefits for practise

The results of the project contribute to the expansion of knowledge about the geological structure and dynamics of the Western Carpathians. In applied research and practice, they represent valuable scientific data for territorial planning, construction activities and assessment of health and natural risks arising from the geological environment. The project results can help in the search and mapping of areas of geohazards and georisks, in the objectification of the probabilistic calculation of the seismic hazard of large construction sites with a significant social impact, in the assessment of geothermal energy sources and in the search for sources of underground water and mineral raw materials.

Fig. 1. / The landscape of the Vikartovce fault - a view from the south on the horst of the Kozie vrchy Mts. in the area of Spišský Štiavnik
(photo by F. Marko).

Fig. 2. / Geological map (A; black line indicates the course of the Vikartovce fault) and location of CSAMT and geophysical profiles (B). Legend: 1. a) detected course, b) estimated course of Vikartovce fault; 2. the detected width of the fracture fault zone, 3. the highest value of Rn in the interior spaces in the village of Vydrník, 4. the occurrence of travertines, 5. the location of survey profiles: a - Kravany, b - Spišský Štiavnik, c - Vydrník, d and e - Spišské Bystré, f - Hranovnica-Dubina (topographic basis: GCI&NFC, 2017-2019)

Fig. 3. / Geologically interpreted section according to CSAMT results along the Vydrník profile.

Fig. 4. / Visit to Tribhuvan University in Kathmandu (Nepal)

Fig. 1

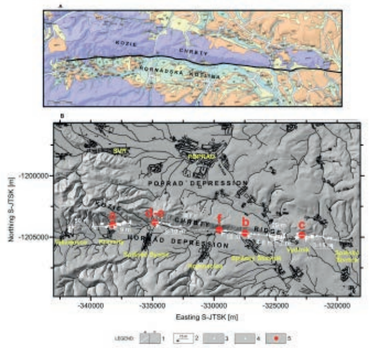

Fig. 2

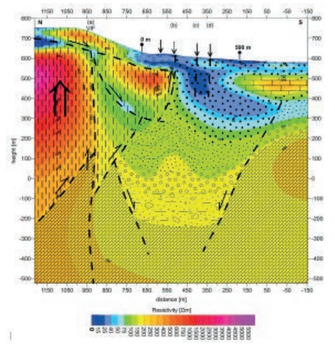

Fig. 3

Fig. 4

Bacteriophage preparations for therapy of vaginal and urinary infection

Principal investigator
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Applicant organisation
Comenius University in Bratislava
Participating organisation
Institute of Molecular Biology SAS
Term of solution
7/2017 — 12/2021
Budget from agency
235 000 €
Project ID
APVV-16-0168

Research subject

Urogenital tract infections (UTI) are frequent bacterial infections. They present a global problem that has a negative impact on human health and requires high economic costs. The increasing number of antibiotic resistant strains complicates UTI treatment options. A phage therapy, meaning the application of viruses infecting bacteria as antibacterial drugs, is one possible way to treatment of resistant pathogens.

Aim of the research

The aim of the project was to prepare a phage cocktail specific for the most common pathogens causing bacterial urogenital infections. We focused mainly on the isolation of bacteriophages infecting uropathogenic *E. coli* strains, which are the most common UTI causes, and on bacteriophages and phage lytic proteins from *S. agalactiae* causing serious neonatal infections.

Achieved results

In the study, we created a collection of clinical bacterial isolates from urine and vaginal swabs of patients and pregnant women, supplemented by some isolates from food and the environment. At the same time, we created a collection of lytic phages infecting these bacteria, which currently contains 19 phages infecting *E. coli*, 12 phages specific for Cronobacter and Enterobacter strains, and two phages infecting *K. pneumoniae* strains.
We classified *E. coli* specific bacteriophages into eight taxonomic groups. We determined that phages from the *Tevenvirinae* subfamily and the *Autographiviridae* family had the widest host range. vKMB26 *Tequatrovirus* had the broadest host specificity, infecting 58% of the strains. It was interesting that closely related phages of the same genus differed mostly in the phage adhesin genes and therefore had different host specificity. Similarly, bacterial strains of the same sequence type differed in susceptibility to phage infection. As a part of the project, we compared differences in RNA polymerase specificity in two closely related phages of the *Autographiviridae* family, Dev-CD-23823 and Dev-CT-57, infecting *Cronobacter* strains, which helped to identify factors contributing to the phage evolution (Fig. 1). Based on the obtained results, we prepared phage cocktails effective for the elimination of selected pathogens causing vaginal and urinary tract infections. We observed that cocktails consisting from our phages possessed efficiency against local *E. coli* and *Enterobacter* strains comparable to commercial phage preparations. We verified the good activity of the cocktail against E. coli growth in liquid culture, the cocktail was efficient mainly on strains from the clonal complexes CC131 and CC73, which are among the most common uropathogens. We also confirmed the effect of the phage cocktail in the simulated urine (Fig. 2). We investigated encapsulating of phage cocktails in alginate capsules as a way to protect phages against the acidic gastric environment during oral administration. We hypothesize that such encapsulated phages are suitable for oral use, which will be able to reduce the amount of uropathogenic *E. coli* in the intestine as reservoirs for the spread to the urogenital tract. We also looked for phages infecting *S. agalactiae* strains, but in accordance with the other authors, we were unable to isolate a lytic phage infecting this species. For this reason, we studied prophages inserted into 28 sequenced *S. agalactiae* genomes. We found that strains contained 1-3 prophages, which we divided into eight groups according to the sequence relatedness. Prophage function was confirmed by induction with mitomycin C in thirteen phage lysates. Isolated tempered phages can be used in further work for the construction of genetically engineered virulent mutants suitable for phage therapy.
The phage lytic proteins are an alternative to phages isolated from the environment. These proteins are characterized by high activity and wide substrate specificity. Enzymes derived from bacteriophages with the ability to disrupt cell walls, such as endolysins and other peptidoglycan hydrolases, are one way to replace conventional antibiotics. As part of the project, we prepared recombinant phage endolysins from three strains of *S. agalactiae*. We overproduced and isolated recombinant endolysins EN534-C, EN533-N and EN572_5-C. We tested the conditions for optimal lytic activity, the effect of pH, Ca^{2+} and NaCl concentrations and the host spectrum of endolysins with respect to bacteria present in the vaginal environment. The obtained endolysins showed antibacterial activity against the target bacterial species (Fig. 3).

Benefits for practise

Phage cocktails and endolysins obtained from the project can be used in the preparation of therapeutics for the treatment of bacterial infections of the urogenital tract.

Fig. 1 / Comparison of the genomes of Dev-CD-23823 and Dev-CT57 phages infecting *Cronobacter* strains with the reference phage vB-CsaP-GAP227
Legend: early genes (pink), DNA metabolism (green), RNA polymerase (red), morphogenesis (blue and purple), lysis (black)

Fig. 2 / Growth inhibition of five *E. coli* strains in a phage cocktail composed of six phages in laboratory LB medium (A) and in artificial urine (B)
Legend: growth of strains in the presence of a phage cocktail (triangle), growth of strains without phages (circle)

Fig. 3 / Lytic activity of recombinant endolysin EN534-C against *Streptococcus agalactiae* CCM 6187.
Legend: sample with endolysin (triangle), control without endolysin (square), the activity was measured spectrophotometrically

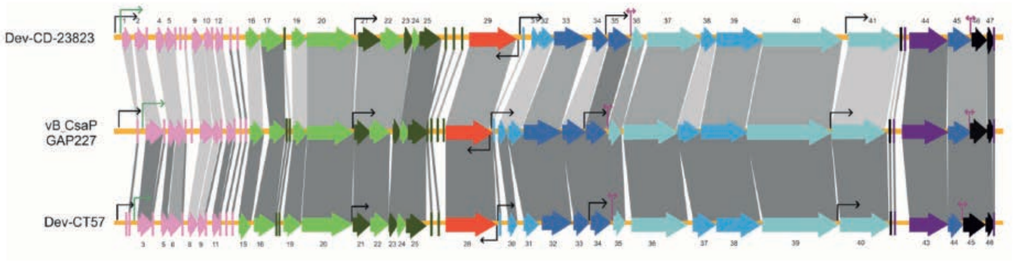

Fig. 1

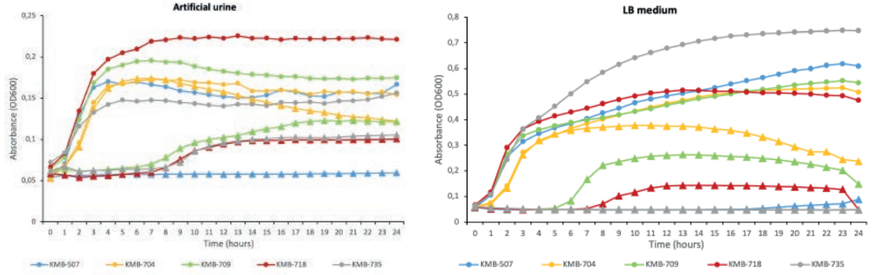

Fig. 2

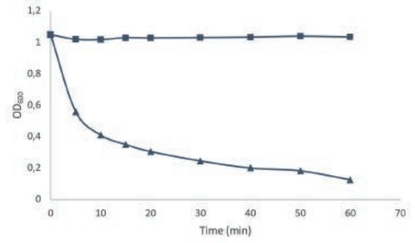

Fig. 3

Progresive methods for elimination of development and spread of bacterial resistance against clinically relevant antibiotics

Principal investigator
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Applicant organisation
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Participating organisations
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Faculty of Science UPJŠ Košice
Term of solution
7/2017 — 12/2020
Budget from agency
200 000 €
Project ID
APVV-16-0171

Research subject

The research subject was to create a picture of the occurrence of selected antibiotic resistant bacteria (ARB) as well as resistance genes (ARG) in the environment, food, animals and people in the Slovakia. Wastewater is an important source of these biological pollutants that can enter the environment and the food chain through surface flows. Due to this, the project verified the effectiveness of advanced degradation procedures in the elimination of ARB and ARG, as a possibility of tertiary wastewater treatment.

Aim of the research

The project was divided into 4 main objectives aimed at solving current problems related to the emergence and spread of antibiotic resistance in the environment.

1. Determination of the ARB and ARG prevalence in selected environments closely related to anthropogenic activity.
2. Microbiological analysis of high-level resistant isolates from individual environments.
3. Study of processes supporting the increase of antibiotic resistance due to environmental stress.
4. Research and use of degradation procedures in the ARB and ARG removal from wastewater.

Achieved results

Both ARB and ARG were confirmed in the intestine of more than half healthy people. A slightly higher ARG incidence was observed in people preferring plant-based diet. This could be related to our observations of ARBs in smoothies. The presence of ARB in the stool of the owner and their pets was demonstrated in 8/10 pairs. In farm animals intended for diary production, we noticed mainly penicillin-resistant staphylococci, which also correlates with the presence of ARB in raw milk confirmed by us. In the case of farm animals and broilers, we mainly observed beta-lactam resistance. ESBLs were detected in broilers already in the first week of their life. We also detected ARGs such as *qnrA*, *qnr B* and *qnrS*. We isolated *E.coli* carrying plasmids with ARG from the environment of the cage. The CMY-2 gene with zoonotic potential was also detected.This can represents a serious health risk for humans. In the case of foods, ARBs were also observed in sushi and poke samples. The presence of ARB was confirmed in all monitored environments, i.e. in waste water of WWTPs, in stabilized sludge, but also in surface waters and their sediments or in public transport. We observed the highest numbers of ARBs in hospital wastewater. High numbers of ARBs were also found in samples of sewage sludge, which is usually applied in agriculture as a fertilizer. In terms of resistance mechanisms, we most often observed efflux pumps overproduction contributing to multidrug resistance. This mode of action was detected especially in isolates from sewage sludge, gut microbiota and some foods. Non-antimicrobial compounds increased the frequency of mutations leading to resistance, especially in lower concentrations found in wastewater. Analysis of ARBs from waste dumps from mining and metallurgical activities, with an environmental burden of high concentrations of heavy metals, showed a high level of antibiotic resistance in these isolates. The most effective elimination technology was the modified Fenton reaction, in which hydroxyl radicals are gradually formed. With this modification, costs and negative effects on the environment are reduced. However, the disadvantage remains the strict control of the pH of the solution, while this pH would also need to be adjusted after each reaction, so it is currently not usable for operation at the WWTP. The use of BDD electrodes and iron oxides has also shown good results, but their effectiveness is dependent on the presence of the number of solid particles that reduce it. We also recorded good results in the case of using nanoparticles.

Benefits for practise

Our results document that ARB and ARG occurs commonly in humans, animals, food and the environment in Slovakia. The major and most important source is wastewater. The use of tertiary treatment of WWTP effluent is therefore essential, and our project has shown that advanced oxidation processes can be a promising route. Sewage sludge can contribute to the contamination of plant-based foods from which smoothie drinks are prepared. With the addition of poor hygiene of the service personnel, secondary contamination can occur, whereby ARBs can further enter the consumers gut the and through the stool into the wastewater, where they are concentrated in stabilized sludge - the circle is closed. Considering that the rendering plant is an important source of ARB and ARG, our data emphasize the importance of adequate protection of working personnel and adherence to strict hygiene measures in the operation of the premises.

Fig. 1. / Heatmap documenting the correlation between increased resistance to metals and antibiotics in isolates from waste heaps from mining activities (Tarnov, Poland, left and Hodruša-Hámre, right).

Fig. 2. / Dissemination of ARB and ARG using wastewater

Fig. 3. /Effect of WWTP and season on occurrence of ARB in wastewater and sewage biofilm

Fig. 4. / Occurrence and distribution of ARBs in smoothie foods

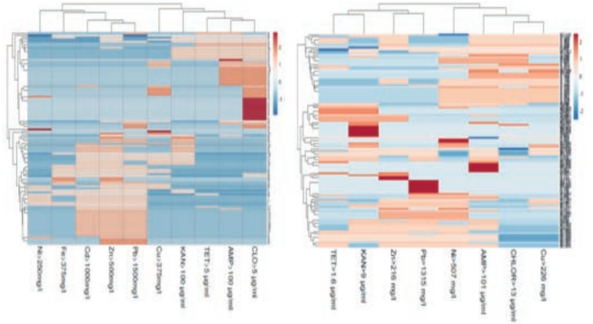
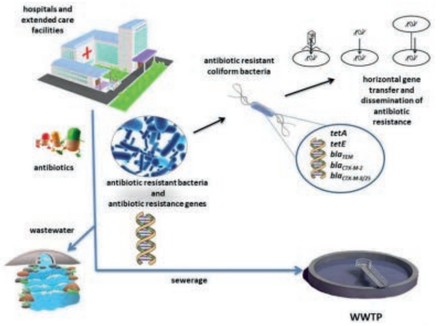


Fig. 1



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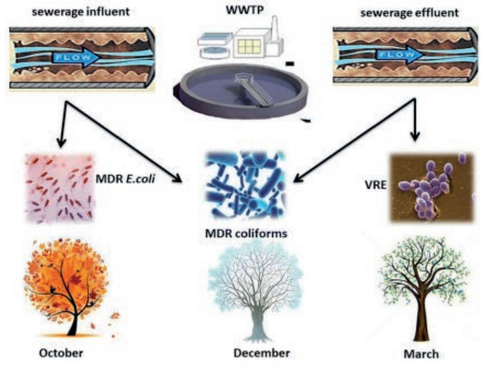

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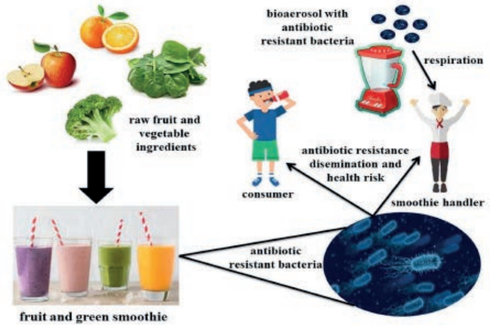

Fig. 4

Targeted modulation of gut microbiota and its transplantation in prevention and treatment of inflammatory bowel diseases

Principal investigator
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Participating organisation
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Term of solution
7/2017 — 12/2021
Budget from agency
249 613 €
Project ID
APVV-16-0176

Research subject

Non-specific inflammatory bowel diseases (IBD), including Crohn's disease and ulcerative colitis (UC), belong to the digestive diseases with a chronic course. They are characterized by a recurrent clinical course and necessary lifelong medication, which lead to a decrease in workability and quality of life in patients. Despite intensive research over several decades, the exact etiology of IBD has not yet been elucidated. It is stated that it is a process resulting from the interaction between intestinal microbiota and the immune system which is genetically predisposed individuals leads to a spontaneous remitting inflammatory process that damages the intestinal wall. Targeted modulation of gut microbiota has the potential to become a new therapeutic approach to the treatment of IBD and most probably can be applied as a preventive approach for genetically predisposed individuals. Antibiotics, prebiotics, synbiotics, postbiotics, various food components and increasingly starting fecal microbiota transplantation (FMT) are currently used in the world for microbiota modulation.

Aim of the research

The project was focused on the study and comparison of the intestinal microbiota composition and diversity in healthy subjects and patients with UC, as well as on the study of the effect of the "healthy" microbiota transplantation and targeted modulation of dysbiotic microbiota using in vitro model of the Simulator of the Human Intestinal Microbial Ecosystem (SHIME) and animal *in vivo* models of pseudo-germ-free (PGF) mice and conventional rats to design new and effective procedures in the prevention and therapy of inflammatory diseases in the digestive tract.

Achieved results

The results of 16S metagenomic sequencing analysis showed significant differences in the composition of the gut microbiota in UC patients and healthy volunteers. Samples from patients with UC showed a significant reduction in the number of bacteria, and a significant reduction in species diversity and variability, which is a typical sign of dysbiosis. An important difference was the presence of Fusobacteria, which were absent in healthy volunteers (their occurrence is associated with the pathogenesis of e.g. colorectal cancer), also there was observed a decrease in representatives of phyla Bacteroidetes and an increase in phyla Proteobacteria with a predominant species of *Escherichia/Shigella*.
A unique in vitro SHIME model was used for the study of intestinal microbiota modulation. SHIME model consists of separate but interconnected glass reactors, representing individual parts of the digestive tract, which simulates the microbial part of digestion in the large intestine. The application of freshly prepared fecal transplant (FMT) from a healthy donor directly into the stabilized microbiota of a patient with UC proved to be the most effective *in vitro* microbiota modification experiment. The result of FMT application was a significant increase in bacteria number, an increase in species diversity, a change in the ratio of Bacteroidetes and Firmicutes phylum, and an enrichment of new species (originating from the donor), mainly producers of butyrate and SCFA (*Bacteroidaceae* and *Lachnospiraceae*). As part of the project, a non-invasive method was developed to obtain an innovative animal PGF model of acute UC (Cells 2020,9,2571; doi:10.3390/cells9122571), and subsequently, an animal model associated with human microbiota was obtained. In addition to the PGF mouse model, a conventional rat model with chemically induced UC was also used to verify the effectiveness of FMT application in a healthy person. In rats treated with FMT, there was a significant reduction in damage to the intestinal epithelium, as well as an increase in microbial diversity (Pathogens 2021,10(2),152; doi.org/10.3390/pathogens10020152).

Benefits for practise

The solution of the project led to the acquisition of original knowledge about the role of intestinal microbiota in UC. The effectiveness of FMT will depend on the composition of the donor's microbiota and the precise control of bacterial phylum. It is also important to clarify the key mechanisms by which FMT has a positive effect on the course of the disease, as well as to specify and more thoroughly define the appropriateness of administering FMT at the current stage of the disease of the patient. These findings will find application in the development of new approaches to the diagnosis and treatment of UC, some of them are already being verified in clinical practice.

Fig. 1 / Taxonomic composition of the gut microbiome of 15 healthy volunteers (K) and 15 ulcerative colitis patients (UC) at the phylum level.

Fig. 2 / Overview of the TWINSHIME setup, consisting of two parallel SHIME systems. Each SHIME reactor contains 5 vessels simulating respectively the stomach, small intestine, ascending colon (A), transverse colon (T) and descending colon (D).

Fig. 3 / Validation of the effectiveness of FMT in an animal PGF model of acute UC (5% DSS) - Experimental design and the timeline.

Fig. 4 / Colonoscopy images from rats: (a) Intestinal mucosa after DSS administration with the presence of many sites of mucosal reddening, profound mucosal bleeding and large fibrin deposits in the lumen; (b) intestinal mucosa after FMT administration with the presence of mucosal reddening and elimination of bleeding; (c) no thickening of the intestinal wall, bleeding or redness were observed in the group of healthy animals.

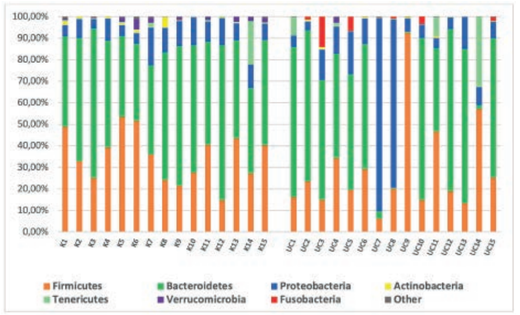
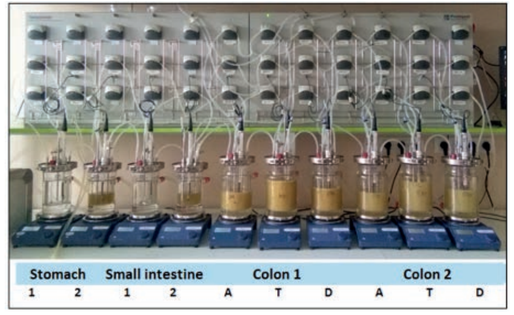


Fig. 1



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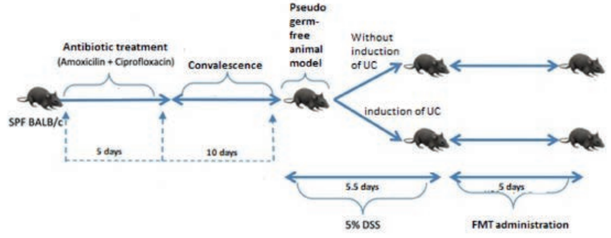
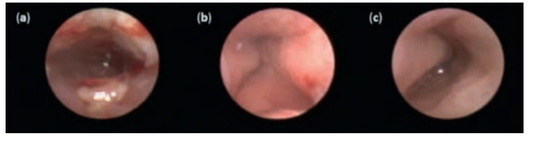


Fig. 3



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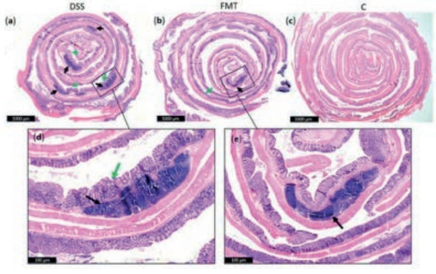

Fig. 5

Fig. 5 / Histopathological changes in colons in Sprague Dawley rats: (a) Numerous lymphoid follicles (black arrow) and aberrant crypts (green arrow) in the colons of acute DSS-induced colitis; (b) reduced damage in colon of rats treated with FMT; (c) no histopathological changes in colon of healthy animals; (d,e) zoom areas of colonic damage. Figure (a–c) magnification 6x; figure (d,e) magnification 16x.

Exotic quantum states of low-dimensional spin and electron systems

Principal investigator
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Applicant organisation
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Participating organisations
Institute of Physics SAS, Institute of Experimental Physics SAS, Technical University of Košice

Term of solution
7/2017 — 12/2021
Budget from agency
170 000 €
Project ID
APVV-16-0186

Research subject

The project was devoted to low-dimensional quantum spin and electron systems, which were examined with the help of advanced computational methods such as exact transformations, tensor-networks methods, perturbation expansions, classical and quantum Monte Carlo simulations, exact diagonalization and renormalization group method. The main subject of the research were exotic quantum states of spin and electron systems as for instance different kinds of quantum spin liquids, unconventional quantum states with character of bound magnons, valence-bond crystals or a subtle order of topological nature. The project has significantly contributed to clarification of a magnetic behavior of low-dimensional magnetic materials. A detailed investigation of quantum entanglement allowed us to establish borders of applicability of spin and electron systems for the sake of quantum computation. The important research topic was also a detailed analysis of thermal and quantum phase transitions.

Aim of the research

The general goal of the project was to provide a comprehensive understanding about diverse manifestations of exotic quantum states of low-dimensional spin and electron systems. The investigated systems have either found their application by an interpretation of unresolved experimental data of magnetic materials or has contributed to a theoretical prediction of the novel quantum states of: a) one-dimensional spin systems; b) spin lattices of different spatial geometry; c) coupled spin and electron systems.

Achieved results

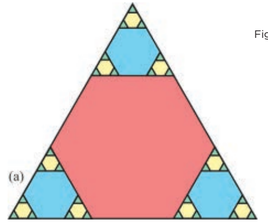
All declared project goals were successfully accomplished in extenso. For one-dimensional spin systems we have clarified nature of dimerized states of orthogonal-dimer chain, quantum spin liquid of trimerized and branched chain, bound-magnon crystal and cluster-based Haldane phases of octahedral chain. Our outcomes have also contributed to clarification of nature of quantum phase transitions of spin chains and ladders driven by the external magnetic or electric field. As far as the lattices of different space dimensionality and geometry are concerned, we have determined universality class (e.g. Ising, Potts or Kosterlitz-Thouless) of a phase transition of various euclidean as well as noneuclidean lattices, which were frequently a direct consequence of some unconventional spin ordering (e.g. topologically nontrivial skyrmion and nematic phase). For the triangular bilayer, triangular-kagomé and Shastry-Sutherland lattices we have shed light on a character of unconventional quantum states, which are manifested in a magnetization process as fractional plateaux. In the field of coupled spin and electron systems we have contributed to explanation of the relation of residual entropy of spin-liquid state with its chirality, the stability of Majorana fermions and possible coexistence of spin and charge orderings. Our research outcomes have also enabled the interpretation of a magnetic behavior of selected materials involving Cu^{2+} iónsas magnetic moment carriers $Cu_9Cl_2(cpa)_6$, $SrCu_2(BO_3)_2$, $Cu_3(P_2O_8OH)_2$, as well as polymeric complexes $[Dy(hfac)_2(CH_3OH)]_2[Cu(dmg)(Hdmg)]_2$ and $[CuMn(L)][Fe(bpb)(CN)_2]ClO_4$. The achieved results of the project thus go beyond the framework of theoretical research and have found their applicability also in the field of experimental physics and material science.
The outcomes of the project were published in total in 82 research papers recorded in Current Contents database, whereby the majority of them were issued in renowned current-contents journals with a high impact factor (e.g. 9x Physical Review B and 18x Physical Review E). The high scientific quality of publication outcomes can be best documented by recording more than 200 SCI citations (when excluding self-citations), which prove a significant consent of the achieved results at an international level. The participation of foreign researchers from 10 different countries by solving the project tasks also proves an international dimension of the project.

Benefits for practise

The project had character of basic research, however, the achieved results have potential applicability by a development of modern quantum technologies exploiting quantum entanglement and topologically nontrivial quantum states of functional magnetic materials. The important added value of the project was a training of young researchers when 9 PhD students were directly involved into the solution of the project tasks, whereby 5 of them has already successfully defended topics of their dissertation theses. The project has additionally allowed a stabilization of 1 young researcher (K. Karľová) by creating postdoctoral position for the duration of more than 2 years and has contributed to a reduction of the outflow of talented young scientists from Slovak research community.

Fig. 1 / (a) Quantum Ising model on Sierpinsky fractal in a transverse magnetic field h_x; (b) the dependence of spontaneous magnetization perpendicular to the magnetic field (black curve) and magnetization induced in the magnetic-field direction (blue curve) at zero temperature; (c) the divergence in the magnetic-field dependence of susceptibility verifying existence of a quantum phase transition [R. Krčmár, J. Genzor, Y. Lee, H. Čenčariková, T. Nishino, A. Gendiar, Tensor-network study of a quantum phase transition on the Sierpinski fractal, Physical Review E 98 (2018) 062114, doi: 10.1103/PhysRevE.98.062114].

Fig. 2 / XY model with ferromagnetic interaction J and antinematic interaction J-1: (a) the dependence of spin angles in a ground state; (b) the phase diagram in the plane J-T with paramagnetic (P), ferromagnetic (FM), antiferronematic (AFN) and canted FM (CFM) phase; (c)-(f) the snapshot configurations of spin angles in the ground state for: (c) J = 0.1, (d) J = 0.2, (e) J = 0.6 a (f) J = 0.8 [M. Žukovič, XY model with antinematic interaction, Physical Review E 99 (2019) 062112, doi: 10.1103/PhysRevE.99.062112].



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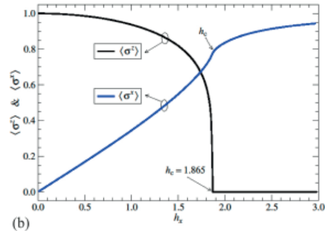

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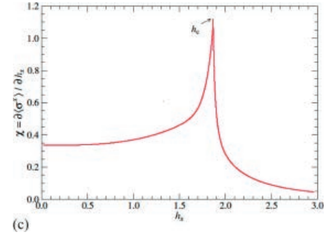

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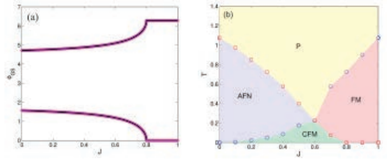

Fig. 2

Fig. 3 /(a) A part of crystal structure of $SrCu_2(BO_3)_2$ affording an experimental realization of the Shastry-Sutherland lattice; (b) the summary of outcomes of magnetic measurements for $SrCu_2(BO_3)_2$ evidencing presence of magnetization plateaux; (c) the theoretical prediction of fractional plateaux for the Heisenberg model on the Shastry-Sutherland lattice; (d)-(f) the microscopic nature of magnetization plateaux corresponding to quantum states with a columnar or a stripe order of triplons (red dimers) on the background of singlet states (white dimers) [T. Verkholyak, J. Strečka, Fractional magnetization plateaux of a spin-1/2 Heisenberg model on the Shastry-Sutherland lattice: effect of quantum XY interdimer coupling, SciPost Physics 12 (2022) 056, doi:10.21468/SciPostPhys.12.2.056].

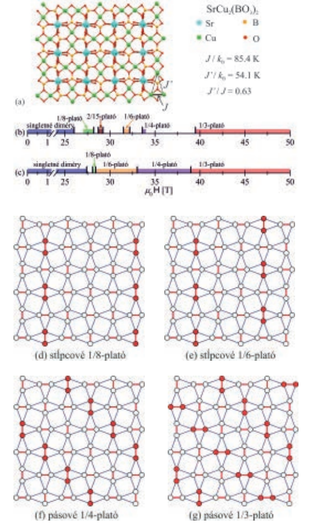

Fig. 3

Functional and taxonomic diversity of wetlands and its relationship to ecosystem processes

Principal investigator
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Participating organisations
Plant Science and Biodiversity Center SAS,
University of Prešov, Matej Bel University in Banská Bystrica
Term of solution
7/2017 — 12/2021
Budget from agency
95 000 €
Project ID
APVV-16-0236

Research subject

Biodiversity changes such as increasing rates of species extinctions and species invasions have a strong potential to alter ecosystem properties and the goods and services they provide to humans. We focused on natural and human-induced changes in the biodiversity of small standing waters (ponds) and their consequences on the functioning of pond ecosystems.

Aim of the research

Using field observations and manipulative experiments, the project followed two main aims: 1) to evaluate the effect of environment and diversity (functional and taxonomic) on ecosystem processes 2) to assess the response of taxonomic and functional diversity to human influence.

Achieved results

Following the first aim, we focused on two ecosystem processes: organic matter decomposition and invasibility. We have shown that density, taxonomic diversity and functional diversity of detritivore organisms positively influence the breakdown rate of organic matter in ponds. However, the effect of taxonomic density and taxonomic diversity is rather indirect, mediated by functional diversity (fig. 1) that agrees with theoretical expectations – functional diversity as a proximal predictor of ecosystem processes. Using a meta-analysis of data from the northern hemisphere, we have shown that despite a similarly tight relationship between the aquatic environment and riparian zone of many ponds and headwater streams, organic matter decomposition is generally faster in the streams than in the ponds. The low diversity and density of detritivores are one of the reasons for the slower breakdown of organic matter in ponds. The dominant role of microbial processes in the process may lead to faster mineralization of nutrients and their release into the aquatic environment and atmosphere. We have also shown that leaf litter traits influence the rate of organic matter decomposition in ponds. Specifically, some alien plants invading riparian zones, such as Canada goldenrod, may provide nutritionally rich leaf litter that exacerbates the decomposition process far beyond the rates observed in the litter of native species. Assessing the invasibility of the ponds, we have shown that man-made ponds and ponds situated in the urbanised landscape have a higher probability of colonization by invasive plants than their native counterparts. In contrast to the environmental context, the diversity of local communities does not seem to play an important role in the invasibility of ponds. Using a factorial manipulative experiment conducted in mesocosms (fig. 2), we found that nutritionally rich leaf litter of invasive goldenrod attracts ovipositing females of some mosquito species leading to a higher number of egg clutches and a higher density of mosquito larvae (fig. 3a). We have also made an important discovery of new invasive mosquito species in Slovakia – *Aedes japonicus*. This species of epidemiological importance is known as a potential vector of several diseases transmissible to humans.

In the second aim of the project, we found that eutrophication of the pond environment affects both taxonomic diversity and functional traits of aquatic organisms. For example, ammonium concentration in water affects the natural distribution of *Ceratophyllum demersum* and also growth rate, body architecture and synthesis of flavonoids in this aquatic plant. Using an example of crustacean *Asellus aquaticus*, we demonstrated that consumption of nutritionally rich organic matter leads to a selection of phenotypes with darker body colouration.

We have also combined paleolimnological and recent monitoring data and showed that communities of Tatra Mts. lakes recovering from atmospheric acidification are significantly affected by ongoing climate change. For example, chironomids *Corynoneura scutellata* group spread towards higher elevations within a decade (fig. 4). Again, key aspects of these changes are the functional traits of the species.

Benefits for practise

Taxonomic and functional diversity are sentinels of anthropic stressors and are tightly linked with ecosystem processes in ponds. The results of our research can be used in conservation management, e.g. a finding that management of mosquito breeding sites and invasive plants should be integrated since both groups tend to positively interact and massively co-occur in floodplain areas. The project also provided an opportunity for the career growth of young researchers; 8 PhD. students participated in this research.

Fig. 1 / Structural equation model linking organic matter brakdown rate (k) with density, taxonomic diversity (richness) and functional diversity of detritivore invertebrates in ponds.

Fig. 2 / Mesocosms were used to assess the influence of invasive plant litter on ecosystem functioning at Technical University in Zvolen.

Fig. 3 / Mesocosms with leaf litter of Canada goldenrod (*Solidago canadensis*) had a higher abundance of mosquito egg clutches than those with leaf litter of native species (a). Eggs of invasive mosquito *Aedes japonicus* newly recorded in Slovakia (b).

Fig. 4 / Changes in the distribution of chironomids *Corynoneura scutellata* group in Tatra Mts. lakes between 2000-2004 (blue line) and 2010-2014 (red line). A shift toward higher elevations is likely caused by climate change and the recent increase of temperatures.

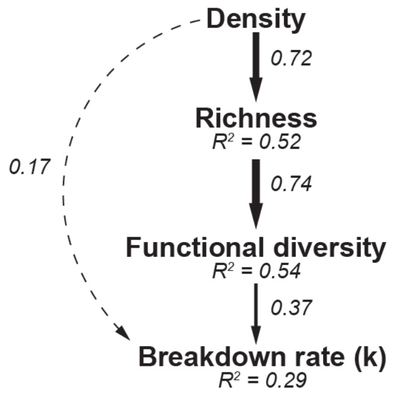

Fig. 1

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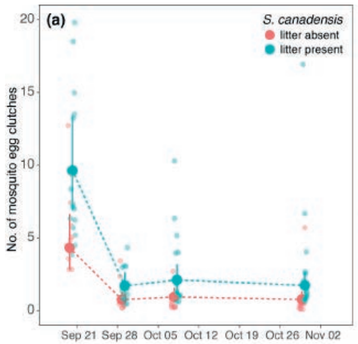

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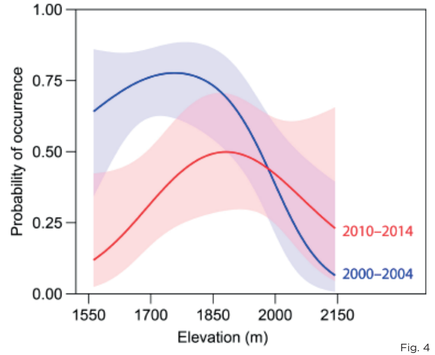

Fig. 4

Utilization of the calcium transport blockers as potential chemotherapeutics in a treatment of solid tumors

Principal investigator
prof. Ing. Oľga Križanová, DrSc.
Applicant organisation
Institute of Clinical and Translational Research, Biomedical Research Centre, SAS
Term of solution
7/2017 — 6/2021
Budget from agency
229 500 €
Project ID
APVV-16-0246

Research subject

Project was focused on changes of the calcium transport in tumor cells, as well as on their functional importance. Calcium signaling is an important regulator of cell metabolism and thus it affects the fate of healthy cells, but also tumor cells. Through its individual calcium transport systems, regulation of the calcium transport can affect either invasivity and cell proliferation of tumor cells, or it can induce apoptosis (programmed cell death) of these cells. Up to now, role of the calcium signaling in tumor cells was not extensively studied yet, therefore, within this project we decided to focus on two special types of calcium transport systems - sodium/calcium exchanger (NCX) a inositol 1,4,5-trisphosphate receptors (IP_3R).

Aim of the research

This project aimed to study changes in the expression of selected calcium transport systems, their physiological/pathophysiological consequences and also the effect of specific blockers for selected calcium transport systems with the impact on apoptosis induction (programmed cell death). We focus on changes in function of the NCX type 1 (NCX1) and the IP_3R type 1 and 3 in tumor cells derived from colorectal carcinoma, but also in cells of different breast tumors.

Achieved results

A. Role of the NCX1 in tumor cells

We described role of the type 1 NCX (NCX1) in regulation of intracellular pH of tumor cells. NCX is an ion exchanger that under normal conditions transports calcium ions out of the cell and sodium ions into the cell. We have focused on the role of NCX1 in hypoxic tumors. These tumors are characterized by initial acidification of the intracellular space, followed by massive transport of protons out of cells. We have shown that during acidification of the intracellular space NCX1 starts to work in the reverse mode, thus transporting sodium ions out of the cell and calcium ions into the cell. NCX1 forms a membrane complex with the sodium- proton exchanger type 1 (NHE1) and also with the carbonic anhydrase IX (CAIX). This complex participates in the regulation of intracellular pH by transporting protons out of the cell through NHE1 followed by simultaneous sodium transport into the cell. In turn, NCX 1 transports excessive sodium out of the cell. CAIX moves protons away from the cell, and thus it prevents formation of high concentration of protons in the vicinity of cell and consequently deactivation of the NHE1.

B. Different effect of individual types of the IP3R in tumor cells

IP_3R are calcium channels, which transport calcium ions from the endoplasmic reticulum to cytoplasm. Up to now, these channels were considered to be proapoptotic, thus participating on the apoptosis induction. We have shown that while type 1 and 2 IP_3R really have proapoptotic effect, type 3 IP_3R operates in the opposite way and this receptor has antiapoptotic and proliferative effects.

C. Modulation of calcium transport by dihydropyridines in two different types of breast tumors

From the point of calcium transport in tumorigenesis, question of dihydropyridine utilization as blockers of calcium transport during cardiovascular problems in women suffering of the breast tumor is interesting. In recently published papers the type of breast tumor was not considered. These tumors are generally very variable and they differ by origin, invasiveness and prognosis. We have performed experimental studies to compare concentration-dependent effects of dihydropyridine nifedipine on levels of intracellular calcium and apoptosis. Also, we compared expression of the IP3R a NCX1 in two different breast cancer cell lines and we have shown that they differently affects migration of the cells.
All our obtained results can contribute to understanding mechanisms ongoing in tumorigenesis. Results of the project were published in 7 renowned international journals with the cumulative IF 30.163. Up to now, these papers were cited more than 80-times.

Benefits for practise

Although the obtained original findings are important preferentially in the basic research, undoubtedly they form basis for development a new therapeutic intervention based on blocking calcium transport through the NCX1 and IP_3R3.

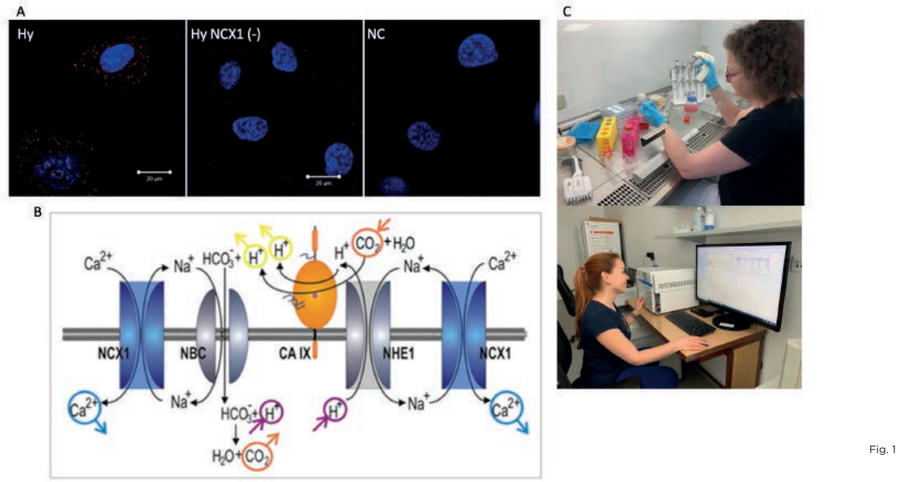

Fig. 1/ As a result of co-localization of the NCX1 and CAIX in hypoxic tumor cells, red dots are formed (A,Hy). These dots diminished in the presence of NCX1 blocker (A, Hy NCX1(-)). Interaction of the NCX1 with NHE1, CAIX and probably also with the bicarbonate transporter (NBC) forms effective tool to extrude protons from the cell in hypoxia (B). Financial sources from APVV enables us to utilize modern experimental approaches, as gene knockout in cells, or flow cytometry (C).

Fig. 2/ Comparison of the expression of individual types of IP_3R from tumor and corresponding healthy tissue from the same patient has shown that expression of the IP_3R1 and also IP_3R2 is deregulated (A,B), while expression of the IP3R3 in tumors is increased (C). In the cells of colorectal carcinoma (DLD1), where the gene of IP_3R3 was knockouted (DLD1/IP_3R3_del), we were able to detect apoptosis (D, green signal). Apoptosis was not detected in nonmodified DLD1 cells (D).

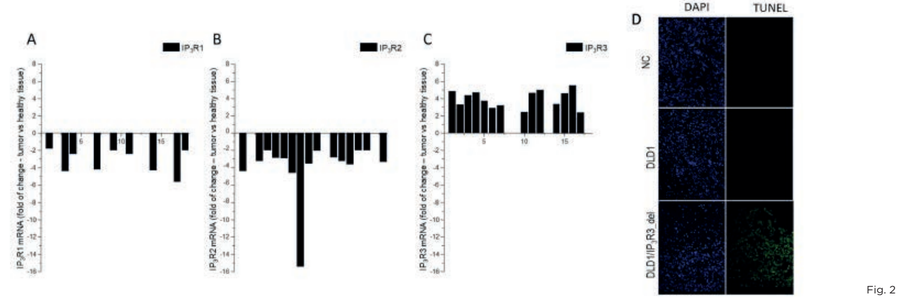

Fig. 2

Develoment of a method for assessment the ecological potential of heavily modified water bodies (HMWB) based on fish communities

Principal investigator
prof. RNDr. Vladimír Kováč, CSc.
Applicant organisation
Comenius University in Bratislava
Participating organisations
Slovak Technical University, Water Research Institute
Term of solution
7/2017 — 7/2021
Budget from agency
249 884 €
Project ID
APVV-16-0253

Research subject

The Water Framework Directive (WFD 2000/60/EC) established a framework for Community action in the field of water policy aimed at protection, maintaining and improving the aquatic environment, as well as at sustainable use of waters in the European Union. European Commission set a timetable to EU member states to prepare River basin management plans, including programmes of measures to achieve good status or potential of the European Water Bodies (WB).

To assess the ecological status of Natural Water Bodies (NWB) in Slovakia, a method based on fish communities (Fish Index of Slovakia; FIS) was developed in 2010, and applied successfully afterwards. In case of heavily modified water bodies (HMWB), good ecological potential is to be achieved as the environmental goal. The ecological potential (EP) poses less strict requirements for the stressors generated by the hydro-morphological changes made in the river beds. To assess EP, new evaluation systems (methods) based on biological elements, including fish communities, were to be developed.

Aim of the research

The main aim of the project was to develop a new method of assessment of the ecological potential of heavily modified water bodies (HMWB) based on fish communities.

Achieved results

A FISHPOT index, derived from FIS (namely from its recent modification FIS21) that has been applied successfully since 2011 to assess ecological status of NWB, was developed during the project.

One of the basic steps to design FISHPOT was to find out if there was a significant relationship (a model) between the values of the Index of Hydromorphological Changes (IHC) and the values of FIS21. To test for such a model, data from 786 WB (656 NWB, and 130 HMWB) were used (Fig. 1).

Searching for the model was based on the following steps: 1) testing the variability of parameters, 2) correlation analysis, 3) regression analysis, 4) regression calculation of FIS21, and 5) validation of the model using the bootstrap method. Based on the above steps, a functional model (Fig. 2) was derived as follows:

FIS21 = -0.13226*IHZ + 0.80489.

Subsequently, the FISHPOT was derived by rescaling the FIS21 values. Specifically, the FIS21 value for each particular HMWB was divided by 0.7739. This was the maximum numerical value of ecological status found for the tested water bodies (Fig. 1), and thus applied as the reference value to define the maximum ecological potential of fish communities in HMWB.

Subsequently, it was necessary to identify boundaries for the FISHPOT values, in order to define five classes of EP. These boundaries (Fig. 3) were set based on a criterion that the proportion of WB, in which the EP fell into a class lower than that of the ES, did not exceed 10 % of all analysed WB.

Finally, FISHPOT was harmonised successfully with other four biological elements, and it is now ready for application.

The second important output of the project was the development of a Method to evaluate the intensity of hydromorphological modifications in montane and submontane streams that can be expressed as the Area Weighted Suitability (AWS) defined from a regression equation. The main advantage of this method is that it requires only basic morphological measurements which can be easily performed in the field using just a basic equipment. In other words, this new method developed during the project is much simpler compared to the traditional SEFA model that requires geodetic measurements of the river bed topography for hydraulic modelling. Statistical testing demonstrated that the new method provides results comparable to those obtained by the SEFA model.

Benefits for practise

The outputs and results of the project (the Method of assessment of the ecological potential of heavily modified water bodies based on fish communities, and the Method to evaluate the intensity of hydromorphological modifications in montane and submontane streams) will be used in the official assessment of ecological potential of HMWB (e.g. regular water quality assessment in Slovakia; assessment of ecological potential for the Water Plan of Slovakia, as well as Management plans for particular river basins; assessment of ecological potential for the International plan of management of the Danube and Tisa river basins; the intercalibration process; bilateral assessment of transboundary water bodies, etc.).

Fig. 1 / Geografic distribution of the Heavily Modified Water Bodies (magenta) and Natural Water Bodies (black) used for the analyses. Author: M. Čistý.

Fig. 2 / The regression model of the relationship between IHC (HYMO) and FIS21.

Fig. 3 / Boundaries for the five classes of the Ecological Potentential defined for FISHPOT.

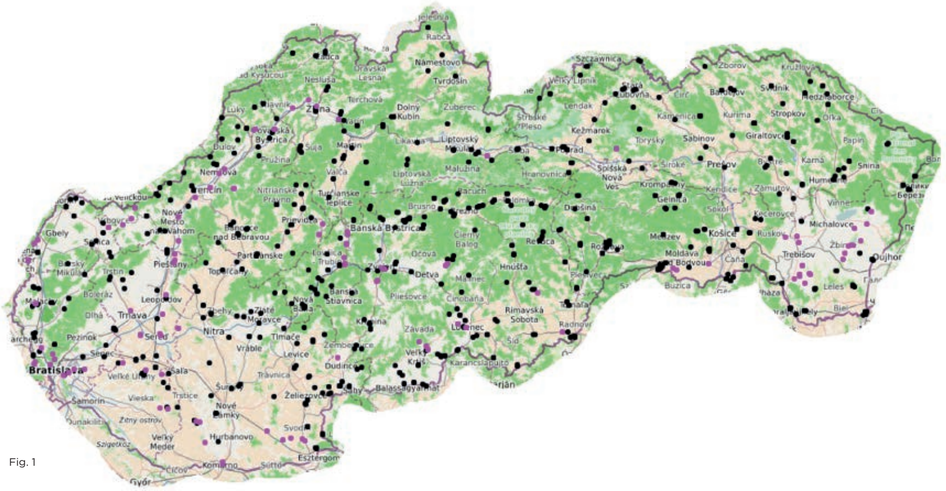

Fig. 1

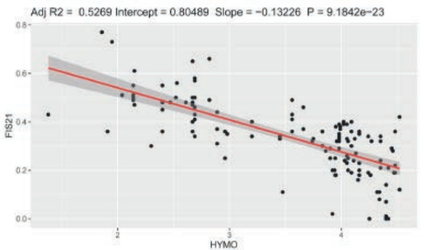

Fig. 2

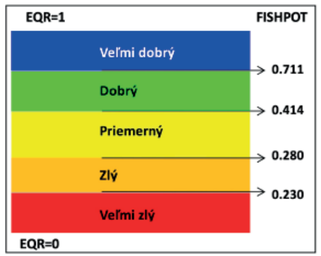

Fig. 3

Integration in the context of generalized measures

Principal investigator
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Applicant organisation
Faculty of Science, Pavol Jozef Šafárik University in Košice
Term of solution
7/2017 — 12/2021
Budget from agency
150 243 €
Project ID
APVV-16-0337

Research subject

The project was dedicated to recent aspects of developing the theory of generalized measures and integrals. Nonadditive measures allow to model the interaction of objects, but several applications in social, behavioral and information sciences require new types of integrals that do not behave additively. They are also the theoretical basis of decision-making methods.

Aim of the research

The main goal was to achieve and publish new original results as basic research in the field of data aggregation using the theory of nonadditive measures and integrals. In the project, generalizations of measures and integrals were developed, including new types of integrals and a detailed examination of their properties, such as integral inequalities, convergence properties of sequences of integrals, generalized integrals on finite spaces, integrals based on level measures and conditional aggregation operators.

Achieved results

In the project we formulated necessary and sufficient conditions for the validity of Hölder-Minkowski type and Chebyshev type integral inequalities for the generalized Sugeno integral, and new classes of functions generalizing comonotone functions (m-subadditive and *-associated functions). These results won the best publication award within the Uncertainty Modeling Conference MDAI 2019 in Milan. Another significant contribution was the detailed study of the class of semi-normed integrals in the context of the transformation theorem, convergence properties of sequences of integrals and integral inequalities. These results also attracted attention in the form of award for the best poster at the international conference FUZZ-IEEE 2019 in New Orleans. This also includes the proposal of new types of integrals for nonnegative real inputs, the so-called upper and lower iterated Sugeno integrals presented in the context of scientometric indices. In the field of research related to generalized level measures and integrals, the project introduced a framework for a natural extension of the classical theory of nonadditive measures and integrals using a new concept based on the outer essential supremum and the corresponding survival function. By abstracting the essential properties of these objects, the concept of conditional aggregation was introduced and investigated in the project. We proved that the generalized Choquet integral can be represented as a classical Choquet integral of a transformed function with respect to a transformed measure defined on the hyperspace of sets. Integrating with respect to these generalized survival functions covers a wide class of well-known integrals (of the type of Choquet-Stieltjes functionals). The advantages of the generalized Choquet integral are also shown in multicriteria decision making. Several theoretical results were used in applications, e.g. when generating activation functions, studying time series, or constructing new bibliometric indices. The results of the project were published in 27 publications in impact journals, which are mostly included in the first quartile according to JCR. The achieved results were presented at several invited lectures at international scientific events. To date, more than 70 citations have been registered in the databases for the publications created within the project.

Benefits for practise

By its nature, the project belongs to basic research. The achieved results significantly expanded the theoretical basis in uncertainty theory, decision processes and nonadditive probability. In particular, original designs of new nonadditive integrals and conditional aggregation operators have great potential in the processing and modeling of multidimensional data, or multicriteria decision-making. The international cooperation created within the project led to cooperation with the world's leading experts in the field of data aggregation and uncertainty modeling with a great benefit mainly for the younger members of the research team. Among the most important results of the project, we include the education of graduates and doctoral students, while 4 diploma and 6 doctoral dissertation theses were related to the project. A significant contribution was the creation of a postdoctoral position within the project, the regular organization of seminars and guest lectures.

Fig. 1 / A simulation of the development of ForeX financial data with a violation of a certain type of convergence (e.g., loss of independence or 1-Lipschitzianity), resulting in a failure of convergence of Kendall's tau (indicated by thick black lines in the figure).

Fig. 2 / Towards to a calculation of the copula integral: the support of the singular copula shown in black, the survival function in red, and the geometric interpretation of the integral in green.

Fig. 3 / Use of the SPOCU activation function in the result of training and validation of the model with the given activation.

Fig. 4 / Invited lecture at the FSTA 2022 international conference in Liptovský Ján

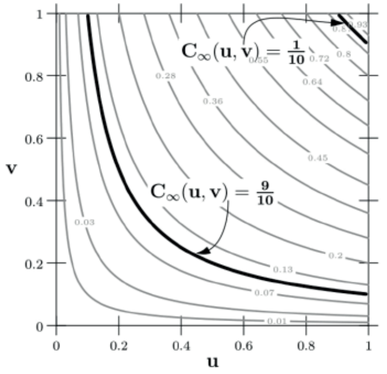


Fig. 1

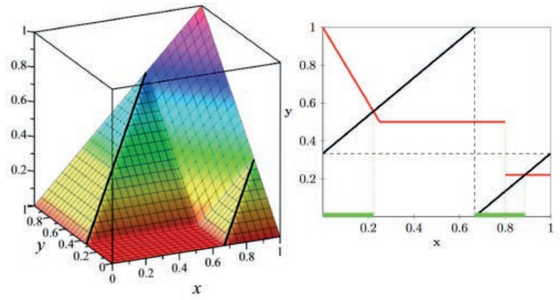


Fig. 2

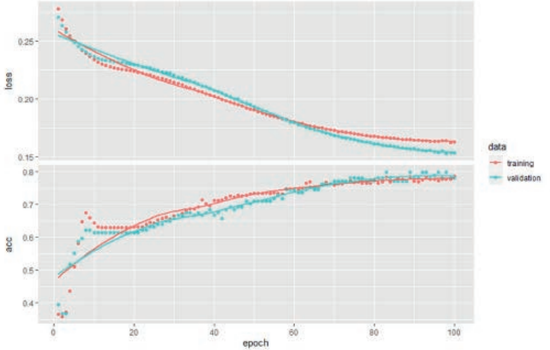


Fig. 3

Fig. 4

The role of neuropeptides and receptors in regulation of endocrine and reproductive organs in the silkworm (Bombyx mori)

Principal investigator
Ing. Ladislav Roller, PhD.
Applicant organisation
Institute of Zoology SAS
Term of solution
7/2017 — 12/2021
Budget from agency
200 000 €
Project ID
APVV-16-0395

Research subject

Insects are the most widespread group of terrestrial animals and owe their evolutionary success to their unique adaptations in their development and reproduction. Important adaptations of organs in insects include the juvenile hormone (JH) producing corpus allatum (CA) and various modifications of the reproductive system. These organs are controlled by regulatory molecules dominated by neuropeptides produced by neurons and endocrine cells. However, the neuroendocrine processes that regulate the function of CA at different stages of development are not well understood. The role of neuropeptides in mating, fertilisation and egg laying is also not well understood. In this project, we used molecular biology and immunohistochemical methods to identify signalling molecules and peptidergic cells, as well as transgenic approaches in combination with physiological and behavioural assays to elucidate the functions of selected neuropeptides and their receptors.

Aim of the research

The aim of the project was to study the expression and function of signalling molecules in the regulation of the reproductive organs and endocrine glands of model insect species. The specific objectives are as follows. 1. identification of receptors for neuropeptides and analysis of their expression in the corpora allata and reproductive organs. 2. identification of peptidergic cells and their products involved in regulation of the primordial gland and reproductive organs. 3. production of transgenic lines for the expression of various effector molecules in neurons and endocrine cells that influence activity of the target organs. 4. analysis of the functions of selected signalling molecules and receptors involved in the regulation of the corpora allata and reproductive organs.

Achieved results

In the silkmoth *Bombyx mori*, we have identified specific neuropeptide receptors in certain parts of the reproductive system and in the endocrine glands corpora allata (CA). We have characterised some of these G protein-coupled receptors and discovered new neuropeptide receptors. We performed expression analyses of the receptors that revealed target cells and organs, suggesting novel roles for the neuropeptides studied. We also described cells producing ligands for receptors found in reproductive organs and CA. Our comprehensive approach provided new data on the distribution and functions of peptides in cells producing ecdysisi triggering hormone receptors, as well as in neurons and endocrine cells producing little-known neuropeptides (e.g. allatostatin CC). A contraction bioassay in vitro showed that four different neuropeptides produced in male-specific neurons MAN9 innervating the reproductive organs stimulate or inhibit the activity of isolated reproductive organs and in this way regulate the movements of seminal fluid during copulation. In the fly D. melanogaster, we have elucidated the signalling pathway of the neuropeptide Ast-C in the diurnal regulation of oogenesis. Our results suggest that Ast-C is the functional counterpart of vertebrate somatostatin. Using transgenic mosquitoes with suppressed expression of specific enzymes in the synthesis of juvenile hormone by CA, we have shown that epoxidation of methyl farnesoate is a key innovation that confers a reproductive advantage to the insect. Our results are important for understanding the molecular mechanisms underlying the regulation of development and reproduction, which require complex neuroendocrine communication between peripheral organs and the CNS.

Benefits for practise

The results of the study of regulatory molecules important for development and reproduction are of both theoretical and practical importance. The basic mechanisms of action of these signalling molecules are similar in all animals, including humans. Our results, obtained in model insects, contribute to the elucidation of the action of hormones at the cellular and molecular level and could therefore be published in high-ranking international journals (Proc Natl Acad Sci USA, Sci Rep, PLOS One). The endocrine system of insects is also being intensively studied as a potential target for the control of insects as vectors of pathogens and insect pests. Although this project was basic research, the knowledge gained can serve as a basis for the development of biotechnologies that halt or alter insect development. The project also contributed to the training of young scientists; 4 PhD students participated in the project.

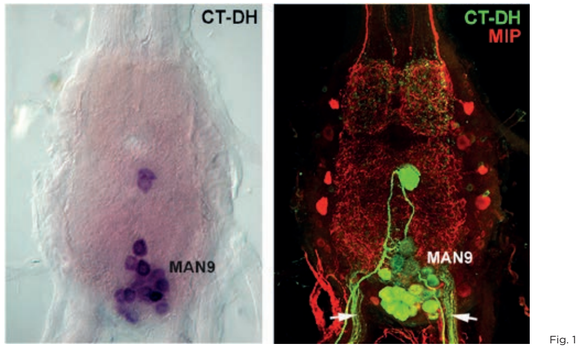
Fig. 1 / Sex-specific neurons MAN9 in the terminal abdominal ganglion of the male silkmoth *Bombyx mori* with colocalised mRNA for the neuropeptide calcitonin (CT-DH) (left, in situ hybridisation) and immunoreactivity (right, immunofluorescence) for CT (green) and myoinhibitory peptides (MIP, red). Arrows indicate the MAN9 processes that innervate the reproductive organs.

Fig. 2 / Effects of the neuropeptides calcitonin (CT-DH) and allatotropin (AT) on spontaneous contractions of the seminal vesicle of the silkmoth *B. mori*, recorded as electrical voltage on a tensiometer transducer. The diagrams on the left show the stimulatory effect of the peptides as a function of dose. The right side shows the recordings of the contractions of the seminal vesicle before and after peptide application.

Fig. 3 / Innervation of the reproductive organs of male *B. mori* by MAN9 neurons. Neuropeptides AT (green), CT-DH (green) and MIP (red) were detected by immunohistochemical staining in the neuronal processes on the surface of the accesoric gland. neuropeptidy AT (zelená), CT-DH (zelená) a MIP (červená).

Fig. 4 / Identification of the receptor for allatotropin (AT) and allatotropin-like peptides (ATL1,2,3) of the silkworm and its functional characterisation in an in vitro Ca2+ binding assay.

Fig. 5 / Identification of a promoter for the neuropeptide ITP by targeted expression of green fluorescent protein (EGFP) in specific neurosecretory cells of the silkworm brain after larval infection with AcMNPV [AACTp-EGFP]. Colocalisation of EGFP (green) and ITP immunoreactivity (red) shows the functionality and specificity of the regulatory region of *itp* gene tested.



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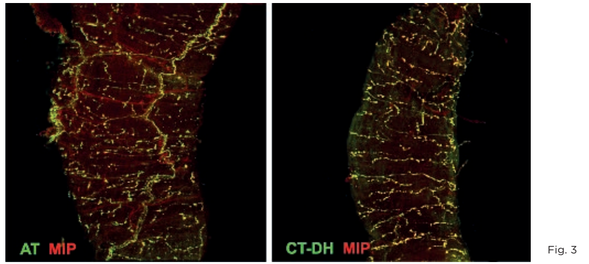

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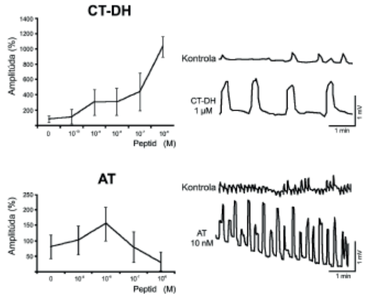
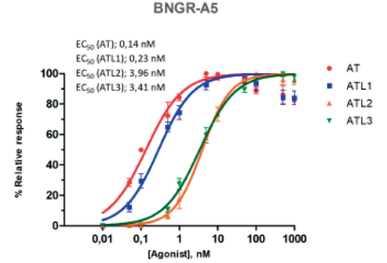


Fig. 2



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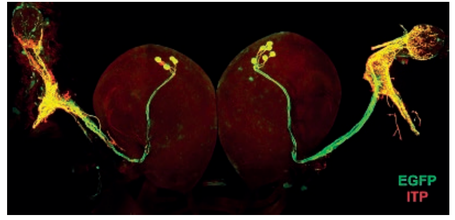

Fig. 5

Functional analysis of synaptotagmins in responses of plants to environmental stresses

Principal investigator
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Applicant organisation
Institute of Botany, Plant Science and Biodiversity Center, Slovak Academy of Sciences, Bratislava
Participating organisations
Comenius University Science Park, Bratislava; Faculty of Natural Sciences, Comenius University, Bratislava; Faculty of Science, Pavol Jozef Šafárik University, Košice
Term of solution
7/2017 — 12/2021
Budget from agency
210 000 €
Project ID
APVV-16-0398

Research subject

Synaptotagmins (SYTs) are well-known calcium sensors in vesicle transport regulating neurotransmitter release in animal nerve cells, but they also have other functions outside the nervous system. Recently, related E-SYTs involved in non-vesicular lipid transfer at sites of contact between the endoplasmic reticulum and the plasma membrane have been characterized. Plants also possess proteins that resemble animal SYTs and E-SYTs by the presence of a transmembrane domain at the N and calcium-binding domains at the C terminus. This project studied plant synaptotagmins in the thale cress (*Arabidopsis thaliana*). There are six homologs in the genome sequence of this model organism, and only AtSYT1, the dominantly and ubiquitously expressed gene of the family, has recently been studied, mainly under *in vitro* conditions, for the role of AtSYT1 protein in responses to various biotic and abiotic stresses. There are only limited data on other SYTs.

Aim of the research

The project aimed to explore the role of plant SYTs in the development and responses to environmental stresses by analyzing the phenotype of the mutants, studying gene expression, characterizing the intracellular localization, trafficking, turnover, biochemical properties and interaction network of the SYT proteins.

Achieved results

We analyzed in detail the spatiotemporal expression of *AtSYT3, AtSYT4* and *AtSYT5* genes. The activities of their promoters were determined by different methods employing the GUS reporter system. The promoters exhibited highly characteristic tissue and cellular specificity, as shown in Figure 1. These results suggest that individual SYTs may have non-redundant functions.
Since there are indications that SYTs play a role in plant stress tolerance, we tested many factors using quantitative fluorometric GUS analysis to determine whether these regulate the expression of *SYTs* genes at the promoter level in advanced seedlings. Some factors, such as cold, ABA, and hydrogen peroxide, had similar effects on the promoter activity of all genes; however, some factors, such as auxins or cytokinins, had a specific impact. Roots were more sensitive to the influences than leaves. We used these findings in testing mutant alleles for individual genes.
The expression of *SYTs* in different organs was also analyzed at the transcriptomic level. We verified the presence of RNA splicing forms. Protein levels in organs were quantified in transgenic plants expressing fusion SYT-Dendra2 proteins under the control of endogenous promoters.
Labeling with fluorescent proteins showed that SYTs are localized at the cell periphery and inside cells, similarly to endoplasmic reticulum markers. Using a pharmacological approach and labeling with the photoconvertible fluorescent protein Dendra2, we characterized the dynamics of AtSYT1. We have shown that the intracellular trafficking of the protein is distinct from that of some other plasma membrane proteins. In this context, we found that Endosidin2, a putative inhibitor of the exocyst complex, acts on the Golgi apparatus. Some aspects are documented in Figure 2.
AtSYT1 has recently come to the forefront of research in several laboratories, and studies have only been done on young *in vitro* seedlings. We analyzed the effect of salt stress on photosynthetic efficiency in advanced control and atsyt1 plants. As expected, we revealed that salinity significantly impaired parameters for stomatal conductance, evapotranspiration, intracellular CO2 concentration, or chlorophyll a fluorescence. The absence of *AtSYT1* gene function increased the negative impact of salt stress on these parameters. The study was complemented by determining levels of critical proteins and pigments involved in photosynthesis, investigating the stomatal system and characterizing AtSYT1 protein dynamics.
In collaboration with our sister Institute of Plant Genetics and Biotechnology and the Institute of Chemistry of the Slovak Academy of Sciences, we analyzed proteome profiles in roots and leaf rosette of control and atsyt1 plants in salt stress. Four hundred forty-six proteins were identified in the roots, for which a statistically significant change in their abundance was observed. A general summary is shown in Figure 3.
We performed screening of insertion mutant lines for *AtSYT3*, *AtSYT4*, and *AtSYT5* genes. These were subjected to molecular biological and morphological investigation. Promising mutant lines are ready for comprehensive phenotypic analysis.

Benefits for practise

Biotic and abiotic factors significantly affect crops' production; therefore, research on the function of genes in response to various environmental stresses is of fundamental importance. The generation of stress-tolerant lines is a crucial task of science. Transformation of plants to overexpress or repress genes involved in plant tolerance to stressors is a promising and easy way to obtain them. However, there are currently too strict restrictions regarding transgenic plants in the EU. The project has been important for the professional development of young scientists. Of the long-term investigators, except for two experienced scientists, all were scientists under 35 years, including five Ph.D. students. The young researchers gained skills in current modern methods.

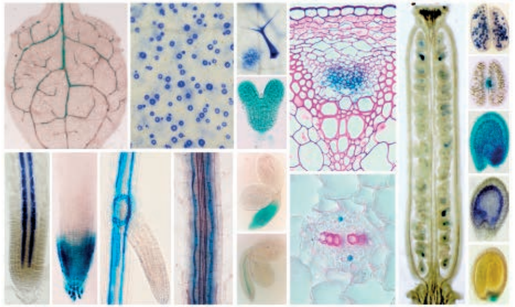


Fig. 1 / Histochemical demonstration (blue color) of *AtSYT* gene promoter activities in different organs of the thale cress using the GUS reporter system.

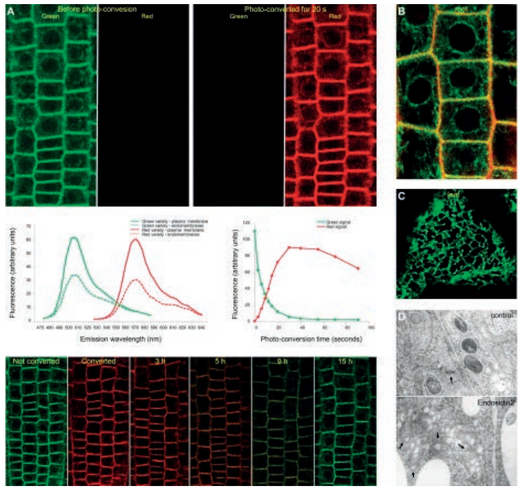


Fig. 2 / Localization of AtSYT proteins. (A) Demonstration of possible application of the photoconvertible protein Dendra2 as a tag to study the protein turnover. The red color represents the converted form of the AtSYT1-Dendra2 fusion protein, and the green represents the AtSYT1-Dendra2 population synthesized after photoconversion. (B) AtSYT5 (green color) and the membrane marker FM-64 (red color) in root cells. (C) Localization of AtSYT1 at the periphery of leaf palisade parenchyma cells. (D) Effect of Endosidin2 on the Golgi apparatus.

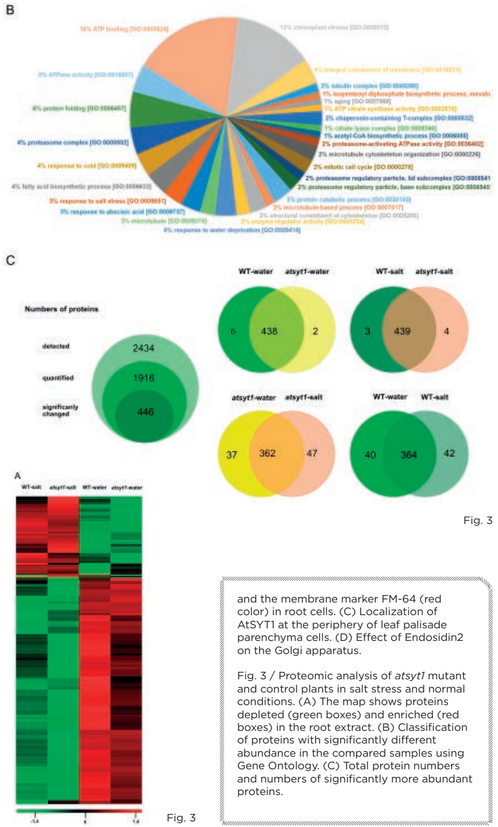


Fig. 3 / Proteomic analysis of *atsyt1* mutant and control plants in salt stress and normal conditions. (A) The map shows proteins depleted (green boxes) and enriched (red boxes) in the root extract. (B) Classification of proteins with significantly different abundance in the compared samples using Gene Ontology. (C) Total protein numbers and numbers of significantly more abundant proteins.

Identification and monitoring Natura 2000 habitats by dynamic segmentation of satellite images

Principal investigator
RNDr. Jozef Šibík, PhD.
Applicant organisation
Plant Science and Biodiversity Center SAS, Institute of Botany
Participating organisation
Faculty of Civil Engineering Slovak University of Technology
Term of solution
7/2017 — 12/2021
Budget from agency
95 000 €
Project ID
APVV-16-0431

Research subject

Scientists from the Institute of Botany of the Plant Science and Biodiversity Center SAS, together with mathematicians from the Faculty of Civil Engineering STU, have combined knowledge from many years of experience in satellite image processing, computer modeling, and long-term vegetation research to develop the NaturaSat software for habitat and plant community exploring and monitoring (Natura 2000 network habitats included).

Aim of the research

Since in Slovakia, more than 600 areas are included in the Natura 2000 network, it is impossible for field researchers to monitor all habitats and check them regularly, as fieldwork is physically demanding and time-consuming. It is often challenging to detect habitat boundaries in hard-accessible terrain. NaturaSat software can replace field habitat mapping with accurate and fast algorithm work using remote sensing methods.

Achieved results

The recently published study of Mikula et al. (2021) introduces NaturaSat software, its powerful new tools such as semi-automatic and automatic segmentation methods, natural numerical networks, and validated examples comparing software results and field survey outputs.

Benefits for practise

The newly developed software makes it possible to accurately locate and classify Natura 2000 habitats and combine their dynamics with the possibility of immediately detecting sudden changes. It supports using Sentinel-2 multispectral data together with various vegetation databases in a customized environment, such as vegetation scientists, field experts, and conservationists. The software is robust enough for researchers, decision-makers, and stakeholders to identify target unit boundaries, even at the habitat level, and automatically identify new habitat occurrences. The deep-learning algorithm developed for the classification of habitats within NaturaSat software can also be used for other research tasks or nature conservation practices, such as identifying ecosystem services and conservation value. Accurate habitat maps obtained from the project can improve many further studies of phytosociology and landscape ecology.

*Mikula, K., Šibíková, M., Ambroz, M., Kollár, M., Ožvat, A. A., Urbán, J., Jarolímek, I. & Šibík, J. 2021. NaturaSat—A Software Tool for Identification, Monitoring and Evaluation of Habitats by Remote Sensing Techniques. Remote Sensing 13/17: 3381. https://www.mdpi.com/2072-4292/13/17/3381

Fig. 1 / Logo of the NaturaSat software and illustration of different spatial scales of remote sensing data.

Fig. 2 / Flowchart of the project work.

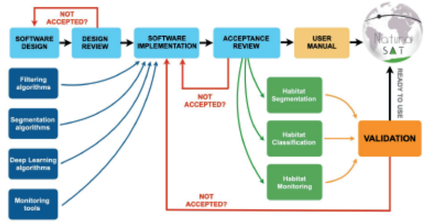
Fig. 3 / User interface of the NaturaSat program – remote data manager.

Fig. 4 / Semi-automatic segmentation (left) and relevancy map (right) of the Natura 2000 habitat 91F0 Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers.

Fig. 5 / Relevancy map of the 91E0 habitat along the Danube River.

Fig. 6 / Ilustration of the new criteria for distinguishing between poplar plantations and native willow-poplar floodplain forests (91E0).

Fig. 1



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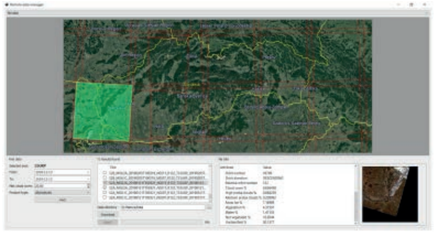
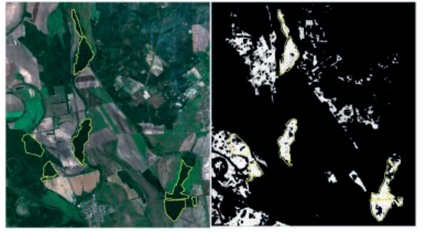


Fig. 3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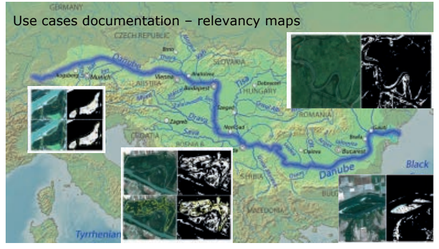

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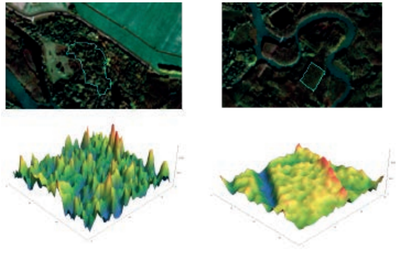
Fig. 6

The application of myrosinase for sulforaphane activation in development of a novel product exhibiting cancer prevention effects

Principal investigator
doc. Ing. Šimkovič Martin, PhD.
Applicant organisation
Faculty of Chemical and Food Technology,
Slovak University of Technology in Bratislava
Participating organisations
Biomedical Research Center of the Slovak Academy of Sciences (SAS), Plant Science and Biodiversity Center SAS, Centre of Biosciences SAS, VUP a.s. in Prievidza
Term of solution
7/2017 — 12/2021
Budget from agency
248 739 €
Project ID
APVV-16-0439

Research subject

Glucoraphanin (GR) is a natural thioglycoside (glucosinolate) that is formed in the tissues of plants from the *Brassicaceae* family. Together with the enzyme myrosinase, it is part of the plant defense system, which protects plants from the negative effects of herbivores and various phytopathogens.
It was found that GR is activated (the thioglycoside bond is splitted into several compounds depending on the conditions) by myrosinase activity released from plant tissues during the mechanical processing of cabbage vegetables (e.g. during food preparation) or during the consumption of cabbage vegetables in the human digestive tract as consequence of the action of extracellular hydrolases of the intestinal microbiome and reactive isothiocyanate, sulforaphane (SFN), is formed. In human cells, SFN acts on several signaling/regulatory factors and pathways (Nrf2/Keap1, MAP, PI3K/AKT/mTRK, NF-κB, c-MYC, VEGH, HIF-1α, MIF and others), which stimulates antioxidant and detoxification mechanisms and leads to suppression of the generation and development of various types of cancer and inflammatory diseases.
GR is a natural source of SFN and is considered an important component of nutrition with preventive effects against the development of some civilization diseases. Its advantage is that it is chemically stable, unlike SFN, and is not subjected to breaking under normal conditions. Currently, GR is offered exclusively as a nutritional supplement in the form of dried or freeze-dried broccoli preparations, which are characterized by low GR content and negligible myrosinase activity.

Aim of the research

The main goal was the preparation of a two-component nutritional supplement that will contain GR and active myrosinase. Part of this goal was the selection of a suitable plant source rich in GR and enzyme, the introduction of analytical methods for the analysis of glucosinolates and myrosinase, the design of an isolation procedure and purification of both key components, recombinant preparation of myrosinase and optimization of its fermentation preparation, characterization of the molecular and catalytic properties of purified and recombinant of the enzyme, immobilization of the recombinant enzyme on a suitable matrix. Another goal was to test the effects of SFN and GR on human and animal tissue cultures of neoplastic cell lines. Changes in the expression of several regulatory proteins playing an important role in the development of cancer and markers responsible for multidrug resistance were monitored in the studied cell lines.

Achieved results

Based on the proposed purification methodology (consisting of 3 phases: extraction of GR from plant material and removal of color pigments with activated charcol, concentration of GR by an ion-exchange chromatography and final polishing of GR on hydroxypropylene dextran matrix using the combined principle of molecular sieve and reversible adsorption) we succeed to prepare GR from *Cardaria draba* with a final purity of >96% and to confirm its identity with HILIC, 1H-NMR and MS-spectrometry. At the same time, it was possible to prepare electrophoretically pure myrosinase with 2 independent procedures. The enzyme was isolated from the seeds of *Lepidium sativum* using the classic isolation approach by protein precipitation with ammonium sulfate at isoelectric pH and affinity chromatography with an immobilized SFN ligand. Also, recombinant enzyme was prepared by expression of the myrosinase gene (TGG1) from *Arabidopsis thaliana* in yeast *Pichia pastoris*. Recombinant preparation of the enzyme was successfully used, through high-density batch fermentation, for semi-operational production of the enzyme. The properties of both myrosinases were successfully described and served to design the conditions for the enzymatic transformation of GR into active SFN. The creation of active SFN was confirmed not only analytically, but also by in vitro testing of the inhibitory effect of nascent SFN on the viability of mouse leukemia cells L1210 and on the growth of selected clinical strains of bacteria and yeast. Flow cytometry, fluorescence microscopy, expression and immunochemical analysis of regulatory proteins involved in cell death processes (Bcl-2, Bax, LC3, cyclins, etc.) showed that SFN in murine leukemia cells induces increased formation of autophagolysosomes and cell death occurs as a result of autophagy.

Benefits for practise

The proposed procedures for obtaining GR and myrosinase can be used in the food or pharmaceutical industry in the preparation of nutritional supplements based on SFN, in the preparation of vegetable and functional foods enriched with GR and myrosinase. The procedures can be used in the preparation of other, analytically pure glucosinolates and enzyme, which are the subject of intensive study.

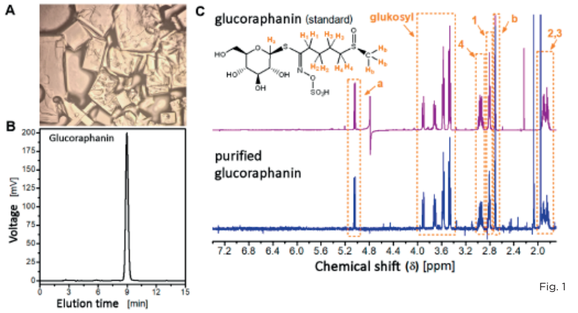

Fig. 1

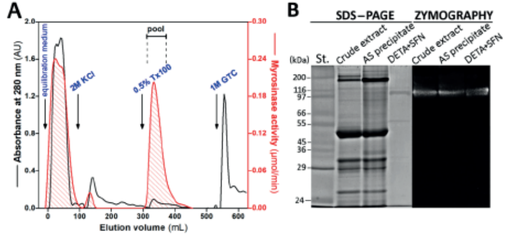

Fig. 2

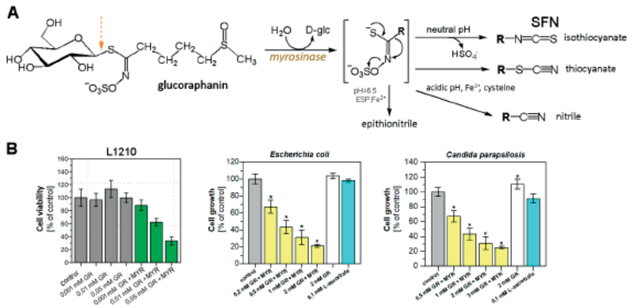

Fig. 3

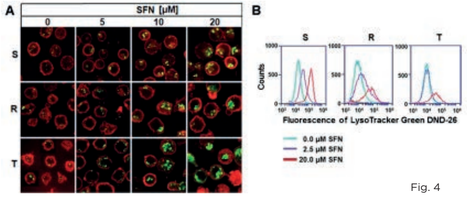

Fig. 4

Fig. 1 / The crystal of glucoraphanin purified from *Cardaria draba* leaves (A), verification of its purity by hydrophilic interaction chromatography (HILIC)(B) and confirmation of identity by 1H-NMR spectroscopy (C).

Fig. 2 / Elution profile of myrosinase from *Lepidium sativum* on an affinity column with immobilized SFN (A). Electrophoretic and zymographic analysis of individual protein fractions captured during the purification of myrosinase (B).

Fig. 3 / Mechanism of glucoraphanin (GR) activation by myrosinase and formation of sulforaphane (SFN) and other hydrolytic products (A). *In vitro* testing of the inhibitory effect of activated GR (by the action of the recombinant enzyme) on the viability of L1210 cells and (created by the action of the purified enzyme from *L. sativum*) on the growth of microbial cells of *Escherichia coli* and *Candida parapsilosis*. Cytotoxic and antimicrobial effects were determined by MTT.

Fig. 4 / Visualization of autophagic vesicles in SFN-exposed L1210 cells using monodansylcadaverine (MDC) (A) and LysoTracker Green DND-26 (LTG) accumulation in lysosomal structures of SFN-exposed L1210 cells (B). Cells (S = sensitive parental line, R = resistant subline and T = line transfected with the gene encoding human P-glycoprotein) were incubated for 24 hours in culture medium with SFN and then labeled with MDC (50 μM)(A) or LTG (75 nM) (B) in the presence of TQR (0.5 μM).

Regulation of Pericellular Proteolysis: From Molecular Mechanisms To Novel Immune Cell Subsets and Therapeutic Tools

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Participating organisations
Institute of Chemistry, Slovak Academy of Sciences
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Term of solution
7/2017 — 6/2021
Budget from agency
193 000 €
Project ID
APVV-16-0452

Predmet a Aim of the research

Proteolytic enzymes, proteases, and their role in immune responses, were the major scientific subject of the project. Proteases play essential roles in many biological processes. Namely, the project focused on the plasminogen system. Plasminogen system, also known as fibrinolytic system, is best characterized by its role in dissolution of fibrin clots during fibrinolysis; however, plasmin, the active form of plasminogen, a central player of the system, is in addition harnessed in a wide variety of other physiological processes: It mediates proteolytic activation of growth factors, e.g. transforming growth factor beta; and, it is fundamental for cell migration by assisting in penetration of tissue barriers, e.g. during inflammation and phagocytosis.
Plasmin activity is under physiological conditions tightly balanced. Instead, a variety of pathologies are associated with imbalanced plasminogen activation, e.g. uncontrolled plasmin contributes to the rampant cell migration during chronic inflammatory diseases or tumour progression, and last but not least, several pathogens highjack plasmin to disseminate. Thus, proteases are promising targets in therapeutic strategies.
The project, in close collaboration with Medical University in Vienna, aimed to delineate novel molecular mechanisms controlling plasminogen system upon immune responses, and to develop novel molecular tools to modulate imbalanced plasminogen activation in various disorders.

Achieved results

The project has delivered two major findings:
First, we have demonstrated, by means of genetic knock-down, knockout, and rescue approaches combined with functional studies, that the protein named CD222 (mannose 6-phosphate/insulin-like growth factor 2 receptor, M6P/IGF2R) is up-regulated on the surface of macrophages, wherein it recognizes plasminogen exposed on the surface of apoptotic cells, and mediates plasminogen-induced efferocytosis, i.e. uptake of apoptotic cells. Our results reveal an up-to-now undetermined function of CD222 in clearance of apoptotic cells, which is crucial for tissue homeostasis (Figure 1). This study was published in the Journal of Leukocyte Biology (DOI: 10.1002/JLB.1AB0417-160RR).
Second, we have shown that human lactoferrin, an iron-binding milk glycoprotein, blocks plasminogen activation on the cell surface by direct binding to plasminogen. We have mapped the mutual binding sites to the N-terminal region of lactoferrin, encompassed also in the bioactive peptide lactoferricin, and kringle 5 of plasminogen. Finally, we have revealed that lactoferrin blocks tumor cell invasion in vitro and also plasminogen activation driven by Borrelia (Figure 2). These results explain many diverse biological properties of lactoferrin and also suggest that lactoferrin may be useful as a potential tool for therapeutic interventions to prevent both invasive malignant cells and virulent bacteria from penetrating host tissues. This study was published in the Journal of Biological Chemistry (10.1074/jbc.RA118.003145).
From these two major outputs the follow-up objectives have arisen, which were forced mainly by the global covid-19 pandemic and the urgent need for new therapeutic and diagnostical tools. Our findings obtained within the project might be useful in the field of research regarding the new coronavirus SARS-CoV2.

First, we have launched new study related to the identification of biomarkers for the diagnosis of pulmonary fibrotic diseases which are one of the worst complications in the so-called "long-covid". Since macrophages, a subject of out up-to-date study, are central in development of this serious disease, we primarily focus on proteins secreted by this subset of immune cells, including CD222.
Second, like several other pathogens, e. g. the afore-mentioned Borrelia, also SARS-CoV-2 uses host proteases to attack target cells, namely the enzyme termed TMPRSS2. This enzyme is highly homologous to plasminogen; thus, we have tested whether lactoferrin and lactoferricin, a second major subject of our research, were able to block TMPRSS2 similarly to plasminogen. We have revealed that both lactoferricin and the corresponding synthetic peptide significantly inhibited not only proteolytic activity of TMPRSS2 but also SARS-CoV-2 infection. Thus, natural and synthetic peptides derived from lactoferrin represent feasible candidates for supporting prevention and treatment of COVID-19..

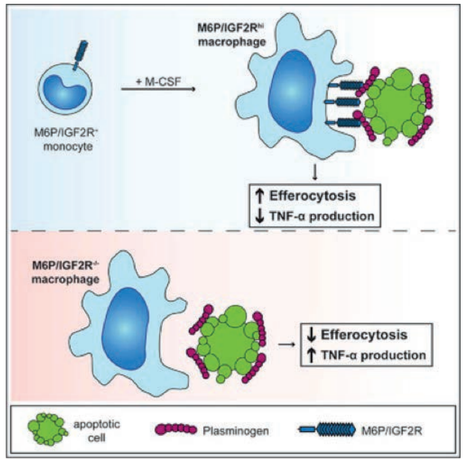

Fig. 1

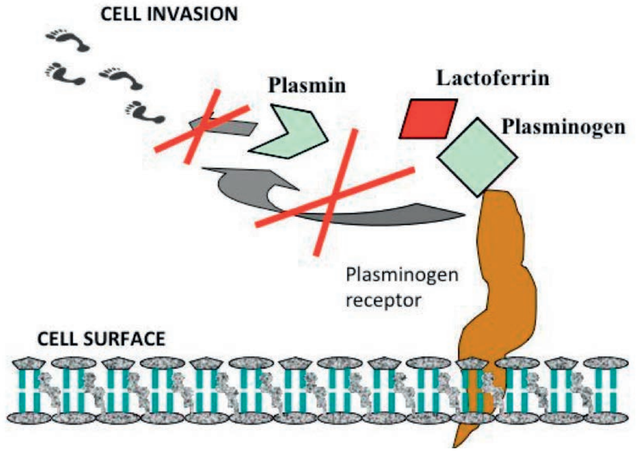

Fig. 2

Fig. 1 / CD222 on macrophages serves as a receptor for apoptotic cells via binding plasminogen.

Fig. 2 / The milk glycoprotein lactoferrin binds to the protease plasminogen and blocks its activation and thus cell migration.

Nanosegregation in soft matter of polymeric and nonpolymeric nature

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Term of solution
7/2017 — 12/2021
Budget from agency
128 713 €
Project ID
APVV-16-0550

Research subject

The research subject was the nanosegregation of non-polymeric and polymeric molecules in liquid systems, i.e. solutions and liquid mixtures.

Aim of the research

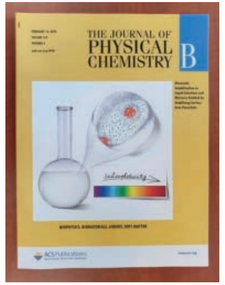
The project was composed at two levels (basic and applied research) and their interconnection. It is an example of how results achieved in the field of basic research can be directly transferred to applications. Our activities in basic research were focused on: (1) nanosegregation of hydrophobic, or more generally of solvophobic substances in liquid mixtures and solutions, (2) nanosegregation of gases in liquids potentially leading to the formation of nanobubbles, which is a very interesting, albeit controversial topic from the point of view of both basic and applied research, and (3) targeted nanosegregation of polymers leading to the formation of polymer nanoparticles for targeted drug transport. In particular, activity (1) was closely connected with the application area, as our goal was to use the knowledge gained from our basic research for patentable methods associated with the detection and removal of hydrophobic contaminants.

Achieved results

The concept of mesoscale solubility was elaborated, reflecting the fact that solubility is achieved not only by the well-known "like likes like" based on molecular solvation, but also by the solubilization of dissimilar substances at the mesoscale level, characterized in that solubility (homogeneous distribution of the substance over the entire volume of the system) is achieved via nanoparticles/nanodroplets with sizes from tens to hundreds of nanometers. The properties of these nanoobjects allowed us to create new patented methods for measuring the content of hydrophobic contaminants and their removal from low molar mass substances and polymers. The topic of eventual nanosegregation of gases emerged during this project, as it turned out that there is an incorrect evaluation of experiments in the literature when nanoparticles interpreted as nanobubbles turned out to be in fact mesoscale structures described in detail within our project. The work on this topic was published in the Journal of Physical Chemistry Letters indexed in the prestigious Nature index with 100% authorship. In the field of nanosegregation of polymers, we obtained valuable results in cooperation with the Institute of Macromolecular Chemistry of the Czech Academy of Sciences and Technion - Israel Institute of Technology. These were polymer nanoparticles based on graft-copolymers synthesized at the Technion, which have a hydrophilic backbone (chitosan or poly(vinyl alcohol)) to which hydrophobic blocks of poly(methyl methacrylate) are grafted. In cooperation with the IMC CAS, we investigated the self-assembly of poly(ethylene oxide)-block-polycaprolactone block copolymers into polymeric micelles capable of targeted delivery of the antibiotic rifampicin to the lungs for the treatment of tuberculosis, which was documented in vivo on Danio rerio fish embryos. We also investigated the possibilities of regulating the rate of micelle degradation in the organism (in macrophages) by polymerizing γ-butyrolactone into a statistical copolymer with ε-caprolactone.

Benefits for practise

The outcomes of the project were protected by submitting a patent application to the European Patent Office. In the course of the project, the Slovak patent office granted us two patents related to nanosegregation. The European application concerns the purification of water-soluble polymers to high levels of purity via removal of hydrophobic contaminants. Water-soluble polymers used in the biomedical field are typically purified by methods such as dialysis and various variants of ultrafiltration, which remove hydrophilic contaminants but not hydrophobic ones. The granted patents relate to new original methods for measuring the content of hydrophobic contaminants and their removal from low molar mass substances. A prototype device and software for measuring the content of hydrophobic contaminants based on laser scattering was developed within this project. The device is highly sensitive and characterized by low manufacturing and operating costs. All these results are immediately usable in practice. Other results regarding polymer drug carriers and the nanobubbles with the perspective of use as an imaging contrast agent mainly for tumor visualization using inexpensive and ubiquitous ultrasonography represent a partial benefit on the way to practical use.



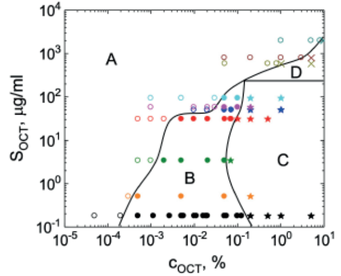


Fig. 1

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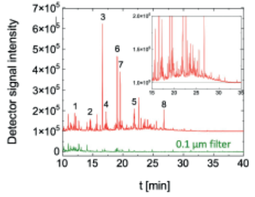

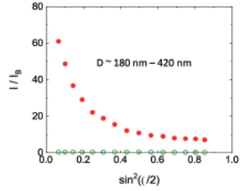

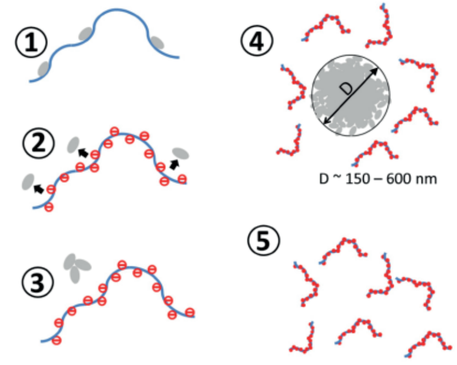

Fig. 3

Fig. 1 / Left: journal cover presenting our work. Right: Diagram of mesoscale solubility limits in the octadecane/ethanol/solvent ternary system. Regions A, B, C, and D represent the regime of full molecular solubility, mesoscale solubility, coexistence of mesoscale solubility with macrophase separation, and the regime of pure macrophase separation, respectively.

Fig. 2 / Prototype device for screening hydrophobic contaminants working on the principle of a patented method of measuring the content of hydrophobic contaminants in water-soluble compounds.

Fig. 3 / Schematic representation of the patented method for purification of water-soluble polymers from hydrophobic contaminants. 1- contaminants adhered to polymer chains, 2- contaminants stripped into water after ionization, 3- nucleation and growth of mesoscale structures, 4- termination of growth, 5- removal of mesoscale structures from the polymer solution by filtration with optimized pore size and filtration pressure. Contaminant removal documented by gas chromatography with mass spectroscopy and by light scattering.

TECHNICAL SCIENCE

Research of new magnetodielectric ceramic and composite material structures

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Participating organisation
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Term of solution
7/2017 — 12/2021
Budget from agency
250 000 €
Project ID
APVV-16-0059

Research subject
Material research of magnetodielectric materials

Aim of the research
- synthesis of magnetically soft ceramic materials (spinels and hexagonal ferrites), analysis of microstructure and optimization of their electromagnetic properties;
- preparation and research of composites based on ferromagnetic fillers and polymeric non-magnetic matrix in order to improve their electromagnetic properties;
- investigation of the influence of selected rare earth and metal cations on selected electromagnetic parameters of magnetodielectrics;
- analysis of the influence of the synthesis method on selected electromagnetic parameters of ferrites and composites;
- innovation of technological equipment for optimal homogenization of input raw materials used in the preparation of developed materials and improvement of the existing automated measuring workplace;
- study of the influence of the composition of vulcanization systems and the type and content of the magnetic filler on the properties of elastomeric magnetic composites. Monitoring the effect of magnetic ceramic filler particle size on their shielding effect and improving their physical-mechanical properties using new types of vulcanization systems;
- modeling the interaction of an external physical quantity (magnetic field, temperature, pressure, thrust) with the structure of the optical fiber and using the results to design optical fiber sensors to sense the spatial distribution of these quantities.

Achieved results
Optimization (with respect to the specific application) of electromagnetic properties of NiZn spinel ferrites by small addition of another ion (Y, La, Eu, Gd, Tb, Ho, Eu, Ce, Dy, Er, In, Nd) and suitable synthesis method (innovated precursor and ceramic method), showed significant changes in the investigated structural and magnetic properties. A metamagnetism was detected in the MnMg system (transition from antiferromagnetic to ferromagnetic state under the influence of temperature under the action of the selected external magnetic field). We have prepared composite materials based on various fillers (spinel and hexagonal ferrites and various allotropic forms of carbon) and polymer matrix (PVC, rubber matrices) in order to improve their electromagnetic material parameters (permeability, permittivity), electromagnetic absorption properties (reflection losses) and physical-mechanical properties (tensile strength, elongation at break, hardness). The small addition of electrically conductive filler (in the form of various allotropic forms of carbon) to the magnetic (ferrite) filler led to improved physical-mechanical properties of composites and also to a shift of the maximum absorption of electromagnetic radiation in the frequency range above 3 GHz. An optical fiber sensor based on the Bragg grating (designed for spatial sensing of the magnetic induction vector) with high sensitivity and dynamic range was designed, implemented and verified. The existing workplace for measuring magnetic and electromagnetic absorption properties of prepared materials was modernized (extension of frequency range of complex permeability and permittivity of material samples above 3 GHz) and technological equipment for optimal homogenization of input raw materials used in preparation of developed materials was modernized (modernization of grinding equipment with regulation of homogenization time and speed per unit time, and innovation of the heating device with the possibility of longer homogenization of the starting solution at a constant temperature). The scientific objectives of the project were fully met.

Benefits for practise
The achieved results in the area of the solved project can be applied in various areas of electrical engineering, electronics and biomedical applications. Attention in this area is focused on the development and research of progressive ceramic and composite materials as well as new methods of testing and measuring materials for practical applications using the latest trends in static, low-frequency and high-frequency measurements as well as non-destructive defectoscopy. When solving the project, emphasis was also placed on the microstructural analysis of materials operating in the mentioned frequency bands. Our goal was also to ensure effective cooperation between the academic and industrial sectors in the field of research and development, both at home and abroad. The materials research carried out in the project also helps to implement progressive technologies in practice. Research in this area increases the added value for the Slovak and foreign electrical engineering and partly also the engineering industries.

Fig. 1 / Spinel $Ni_{0.42}Zn_{0.58}Y_{0.1}Fe_{1.9}O_4$ ferrite particles at 5000x magnification.

Fig. 2 / Temperature dependences of magnetic susceptibility for synthesized spinel $Ni_{1-x-y-z}Zn_xCu_yCo_zFe_2O_4$ ferrites.

Fig. 3. / The hysteresis loops of prepared spinel $Ni_{0.42}Zn_{0.58}Y_zFe_{2-z}O_4$ ferrites.

Fig. 4. / Frequency dependences of real and imaginary parts of complex (relative) permeability for prepared ferrites.

Fig. 5. / Frequency dependences of return loss for prepared MnZn/CB/PVC composite materials.

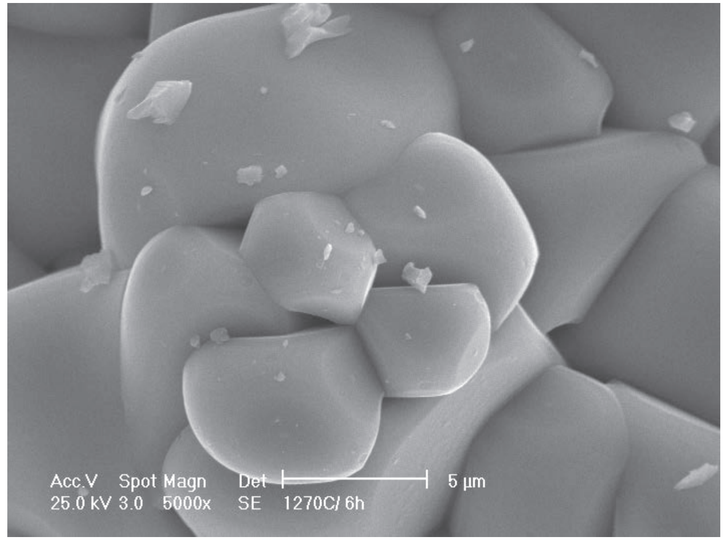
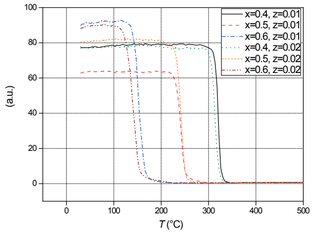


Fig. 1



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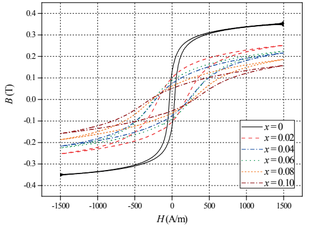

Fig. 3

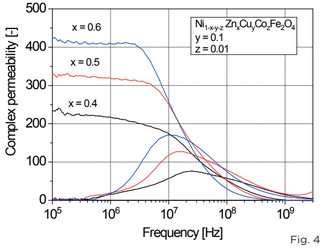

Fig. 4

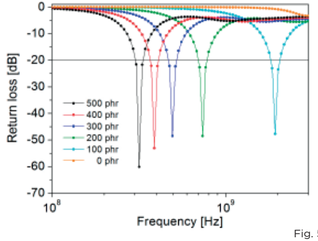

Fig. 5

Skyrmions in ferromagnetic nanoobjects

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Term of solution
7/2017 — 12/2021
Budget from agency
250 000 €
Project ID
APVV-16-0068

Research subject

Magnetic skyrmions are promising candidates for information carriers in efficient computer memories and logic gates of the future. In this project, we focused on the numerical and experimental study of skyrmions in ferromagnetic nanoobjects. Skyrmions have been detected in multi-layered structures, where coupling due to geometry can significantly increase skyrmion stability. Controlling this stability and experimentally investigating suitable structures has therefore been a major challenge. In the project, we focused on the generation and development of methods for the identification and characterization of skyrmion states, but also on the development of a new methodology of magnetic force microscopy (so-called Vortex Core MFM) for mapping small magnetic objects. The results of the project showed the possibility of implementing skyrmions in magnetic components based on shaped nano-objects.

Aim of the research

In this project, we focused on numerical simulations and experimental observations of skyrmions in ferromagnetic nanodots. The stability of skyrmions was increased by the multilayered composition of the materials as well as the geometrical constraint. Nanodot research could lead to room-temperature devices with a reconfigurable magnetic state. Since the control and characterization of such structures is difficult at the current state of knowledge, we focused on simplifying the technique of preparation, identification and characterization of skyrmion states. Our knowledge will help to implement skyrmions in magnetic devices based on shaped nano-objects.

Achieved results

In the project, we focused on the calculation of the free energy surfaces of magnetic systems using algorithm of metadynamics. Knowing the height of the energy barriers that separate the different states in the system is critical for determining the long-term stability of information stored in magnetic memories. However, this information is difficult to obtain directly using simulations of standard microscopic models due to the time-scaling problem arising from the fact that the transition between two minima has the character of a random system (Fig. 1.). We present the effectiveness of the new approach on the example of the magnetic vortex formation in a nanodot with reduced symmetry. Using the reconstruction of the free energy surface, we identified the origin of symmetry breaking during vortex formation, when one polarity of the vortex is preferred despite the fact that an external magnetic field is applied in the plane of the dot process. In our work, we show that it is possible to construct a free energy profile using the metadynamics algorithm.

Next, we focused on the controlled transport of skyrmions in magnetic antidot lattices. Skyrmion based devices will require precise control of skyrmion transport. We show that this goal can be achieved by using a magnetic antidot grid, i.e. of a square grid of circular holes formed in a ferromagnetic layer. We investigate the movement of skyrmions in antidot lattices using micromagnetic simulations and semi-analytical calculations based on the Thiele equation, where skyrmions are driven by applying an electric current. We show that the motion of skyrmions can be controlled in the antidot lattice depending on the parameters of the applied current pulse with a fixed direction. This is possible due to the non-trivial interplay between the lattice antidot repulsive potential, the skyrmion Hall effect and the non-uniform current distribution. We demonstrate that the direction of movement of skyrmions can be controlled by changing the amplitude and duration of the current pulse.

In further work, we observed skyrmions in nanodiscs produced by electron lithography and etching. The nanodisks were composed of a Pt/Co/Au multilayer, which exhibits interfacial Dzyaloshinskii-Moriya interaction and perpendicular magnetic anisotropy. In the discs with a diameter of 150–525 nm, we investigated the stabilization of various magnetic states, such as single-domain state, skyrmion state, and also horseshoe- and worm-like domain structures. We show that six repetitions of the Pt/Co/Au multilayer are sufficient to stabilize the skyrmion state inside the nanodisk at room temperature. We demonstrate the process of creating a skyrmion in nanodiscs by micromagnetic simulations. We found that the field generated by the magnetic tip significantly affects the magnetization state of the nanodisk and leads to the formation of skyrmions. The simulation explains the development of the magnetic state in the disk during its scanning by a magnetic force microscope and confirms the possibility of skyrmion formation. A key transition in this process is the formation of an intermediate, horse-shoe shaped magnetic state.

Benefits for practise

The project had the character of basic research and individual results have the potential to be used in practice. The generation and development of methods for setting up and characterizing skyrmion states is of great importance. Also, the development of a new methodology of magnetic force microscopy (the so-called Vortex Core MFM) for mapping small magnetic objects can have an impact on the development of the so-called quantitative methodology of MFM. The results of the project also pointed to the possibilities of implementing skyrmions in magnetic devices based on shaped nanoobjects, which can be used in selected device applications in the future.

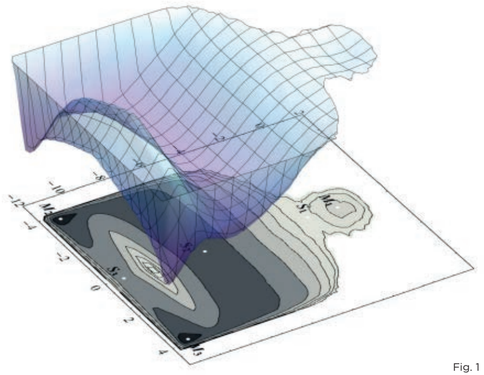

Fig. 1

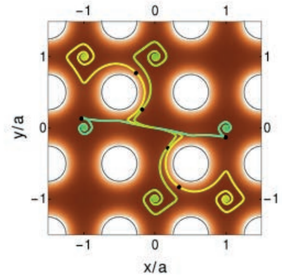

Fig. 2

Fig. 1 / Figure shows the free energy surface of a nanodot reconstructed using metadynamics algorithm. On the free energy map, it is possible to identify the local minimum M1 as well as two symmetry-linked minima M2 and M3 corresponding to the positive or negative polarization of the magnetic vortex.

Fig. 2 / Trajectories of skyrmions in the antidot grid for different amplitudes of the applied current pulse.

Fig. 3 / Schematic representation of a multilayer nanodisk consisting of ultrathin Co layers placed between two different heavy metals, Au and Pt (left). Array of multilayers disks are scanned by the MFM tip (center) and their magnetic state changes during the scan (top right), while the obtained states correspond to the simulations (bottom right).

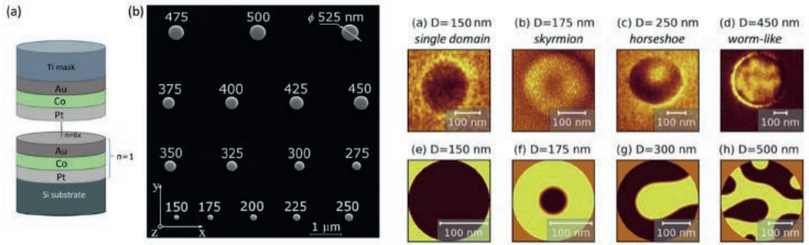

Fig. 3

Elastomeric blends and composites for special applications

Principal investigator
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Applicant organisation
Slovak University of Technology in Bratislava
Participating organisation
VIPO a.s. Partizánske
Term of solution
7/2017 — 11/2020
Budget from agency
248 150 €
Project ID
APVV-16-0136

Research subject

The goal of the project was fabrication and evaluation of properties of blends and composites based on magnetic hard and soft ferrites, or hybrid fillers.

Aim of the research

The aim of the project was research of flexible magneto-polymer, blending and composite materials by application of magnetic soft and magnetic hard ferrites as micro- and nanopowders into rubber compounds showing excellent flexibility, easy formability, good magnetic properties, suitable rheological and physical-mechanical properties.

Achieved results

Within the project solution was experimentally tested the influence of the two types of magnetic hard ferrites (barium and strontium) into rubber compounds based on polar and nonpolar rubbers. The results showed that application of magnetic hard ferrites into rubber matrices led to the fabrication of flexible composites with permanent magnets characteristics. Simultaneously the research was focused on application of magnetic soft ferrites into rubber matrices to prepare ferrite composite materials able to shield electromagnetic radiation emitted from various electronic and radiation sources. It was revealed that incorporation of laboratory prepared ferrites (lithium ferrite, manganese-zinc ferrite) into acrylonitrile butadiene rubber NBR resulted in the fabrication of composite materials, which are able to shield electromagnetic radiation mostly by absorption mechanisms. Based on those positive results, commercially available manganese-zinc ferrite was also tested. Its application into rubber matrix also resulted in the preparation of composite shields with effective absorption of electromagnetic radiation. It was also found out that with the increase in magnetic filler content the absorption maxima and absorption shielding performance of composites shifted to lower frequencies of electromagnetic radiation.

Ferrites filler were applied into rubber matrices based on nonpolar rubbers (butadiene rubber BR, styrene butadiene rubber SBR) as well as polar rubbers (two types of NBR with different viscosities). The experimentally obtained results from determination of cross-link density, physical-mechanical properties and microscopic analysis revealed that adhesion and mutual compatibility between magnetic filler and rubber matrix was improved with rubber matrix polarity. It can be stated that mostly polar rubbers are suitable for fabrication of elastomer magnetic composites owing to their better compatibility with ferrites.
In addition to standard sulfur-based curing systems, peroxide curing systems were used for cross-linking of rubber matrices. It was shown that combination of organic peroxide with suitable co-agent for cross-linking of rubber compounds paves the way for fabrication of composites not only with good magnetic properties but also with enhanced physical-mechanical characteristics. This can be attributed to the formation of more complex cross-linked structure within the rubber matrix and improvement of adhesion on interfacial conditions filler-rubber. The results demonstrated that it is possible to easily modify mainly physical-mechanical properties of rubber magnetic composites by the change in composition of curing systems without negative influence on magnetic and thermo-physical properties or ageing of composites.

Benefits for practise

Based on positive results achieved on lab scale it was also performed fabrication of composite materials with suitable combination of ferrite, limestone and reinforcing filler – carbon black and other processing additives in industrial scale. Fabricated composites were subsequently used for insulation of electric conductors and underwent the operating tests in Bizlink Technology, s.r.o. in Trenčianske Bohuslavice.
The results obtained during the project solution were published in renowned domestic, but mainly foreign current contents journals and presented in form of posters and lectures on domestic and international scientific conferences. From the application potential, the main output of the project solution was submitted patent – Electric conductor with electromagnetic radiation shielding and the way of its production.

Fig. 1 / Frequency dependence of return loss of composite materials with content of 200 phr ferites (F) and different content of carbon black (S), calcium carbonate (V) and processing agents (WB, WL)

Fig. 2 / The influence of composite materials composition on elongation at break.

Fig. 3 / Results of frequency dependence of transfer modulus measurements with vertical /a/ or horizontal /b/ polarization of antenna.

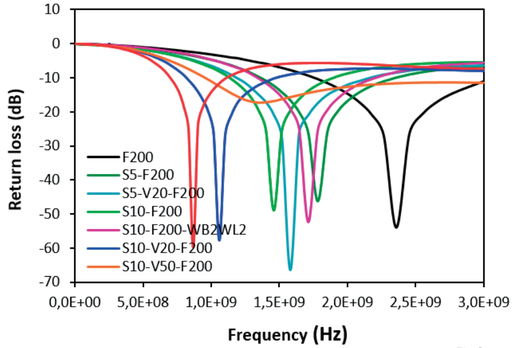

Fig. 1

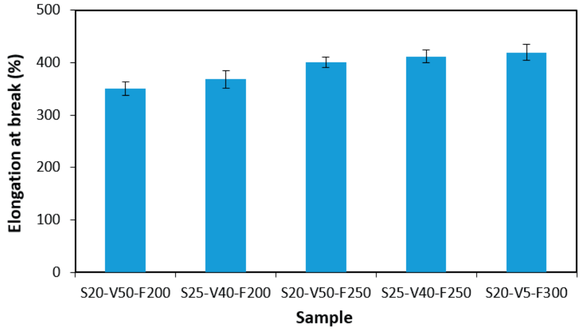

Fig. 2

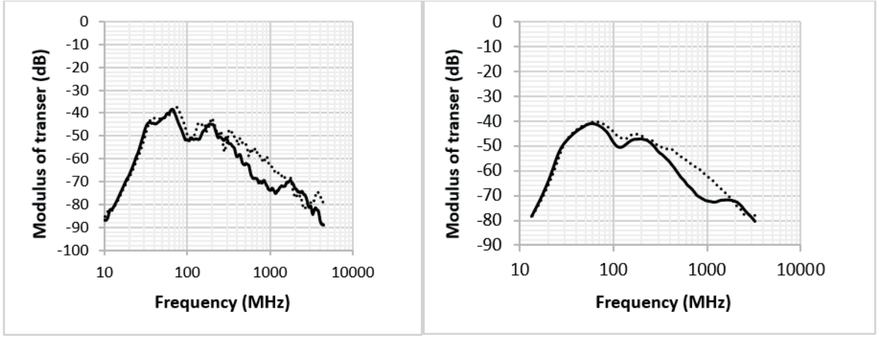

Fig. 3

Progressive modifications of the wood surface, film-forming materials and their interactions at the phase interface

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Technical University in Zvolen
Participating organisation
VIPO, a. s., Partizánske
Term of solution
7/2017 — 12/2021
Budget from agency
249 220 €
Project ID
APVV-16-0177

Research subject

The project aim was to study the properties of the wood surface and physical-chemical modifications of the wood surface and film-forming materials; to control interactions between wood and the materials in both liquid and solid phases. Several factors were inspected, including an ageing process, affecting these properties and interactions.

Aim of the research

The main goal of the project was to determine the number of wood surface properties; recognize the physical and chemical background of the changes corresponding to the specific physical and chemical modifications, and optimize processes of wood surface treatment and gluing.

Achieved results

The research on the surfaces of wood and wood materials processed by various mechanical ways, electromagnetic radiation, thermal treatment, hydro-thermo-mechanical pre-treatment, gas ammonium, plasma, and nanoparticles, generated an extensive database of results comprising chemical changes concerning the wood surface at the atomic level, the main wood chemical components, micro and submicron structure, morphology, and various surface properties (color, wettability, thermo-dynamic characteristics, etc.).
The recognized relations between the chemical changes and the changes in the observed properties enhanced the knowledge about physical and chemical changes in the color space, hydrophobicity, and hydrophilicity, and, consequently, give insight into the mechanisms driving these changes.
For CO_2 laser treatment of wood, the total radiation dose *H*, summarizing all laser properties, was proposed. A close correlation between *H* and observed properties has been confirmed (Fig. 1, Fig. 2). The results obtained can be applied by using a laser beam to create targeted colour patterns on the wood surface, with more plasticity and more colour quality.
The study of wood-liquid and wood-solid substance systems improved substantially the theory of interactions at the wood-liquid and wood-solid coating interface. Based on the results, it is possible to predict optimal wood moisture content for surface coating and gluing applications and to set the critical moisture content level allowable for these technologies. The results enabled to design of methods for identifying causes of wood coatings defects in commercially produced wood materials. These methods were successfully implemented in industrial practice, in specifying causes of problematic hardening of coatings applied on fibreboards, lowering the coating adhesion to the substrate and adhesion between the coating system layers (Fig. 3).
Interactions recognized between wooden particles, adhesive, and PET particles served to propose the process of surface modification of the particles, the optimal ratio of particle board components, and gluing technology procedure, with commercially available adhesives used for the particleboards production (Patent No. 307273, 09. 05. 2018).
We prepared and tested pigmented and transparent coating systems (CS). The targeted modification of these CS significantly improved the material color stability in the ageing process. An example is a three-layer coating system with the middle layer containing microcapsules with self-repairing functions, and the top layer based on the newest acrylate dispersion, possessing a self-chain-networking function and enhanced water resistivity. The modification of CS with ions, colloidal silver, and powdered creatine prepared from sheep wool improved the microbiological stability of these substances.
There were proposed novel, more effective modifications of polycondensation adhesives, using ceratin, cysteine, and cystine, all prepared from sheep wool. These substances reduce the toxicity of wood products glued with urea-formaldehyde adhesives, caused by their hydrolysis and release, while the physical and mechanical properties of the products are preserved. The application of 0.5% of cysteine exhibited a 44% reduction impact on released formaldehyde compared to the control sample. The tested biopolymer samples showed promising potential in applying the novel, more effective environmental trappers of free formaldehyde.
Publication outputs: monographs – 3, CCC – 24, WOS – 25, other 50

Benefits for practise

Some industrial applications are presented in the results. The project generated one realized patent, 4 utility patterns, 6 realized technologies and 2 new products. The research results achieved on CS and adhesives exhibited benefits for producers and users of film-forming materials.

Fig. 1 / Morphology of the oak wood surface perpendicular to the grain after an engraving by CO_2 laser.
a) profiles of the roughness of a reference sample and a sample after a laser treatment – H = 61,7 J.cm^{-2}, b) a dependency of the roughness parameter Ra on total radiation dose H, c) a cross section.

Fig. 2 / A dependency of oak wood color coordinates and total color difference on radiation dose of CO_2 laser.

Fig. 3 / The surface of particleboard: a) before the surface treatment, b) after the surface treatment – cracking and peeling of the coating, c) and d) the surface of particleboard at the defect with a higher concentration of paraffin identified by free surface energy.

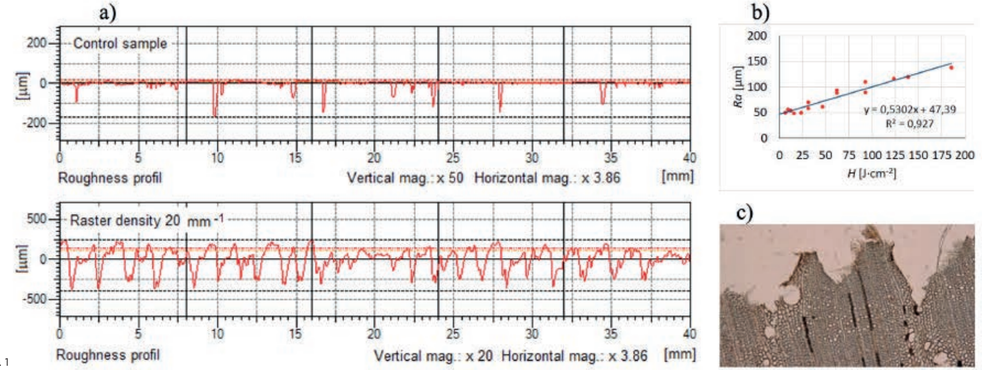

Fig. 1

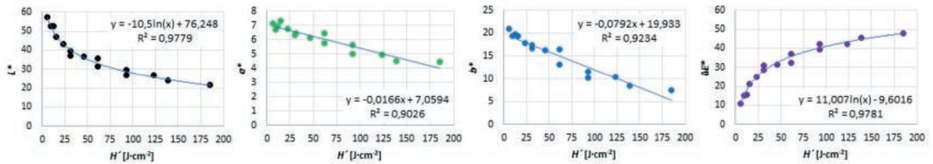

Fig. 2

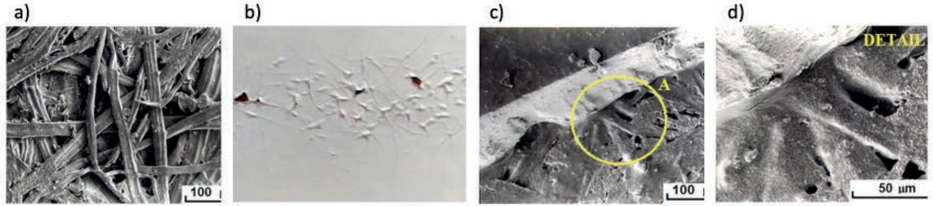

Fig. 3

Research on increasing the energy efficiency of multivalent systems based on renewable energy sources

Principal investigator
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Applicant organisation
Technical University in Košice
Term of solution
7/2017 — 12/2021
Budget from agency
199 987 €
Project ID
APVV-16-0192

Research subject

The REFRES project addressed the issue of increasing the efficiency of multivalent systems based on renewable energy sources, focusing on predictability, synergy effects, optimisation of efficiency and effectiveness of such a system with the primary goal of increasing energy efficiency.
The project dealt with the research of algorithms for highly efficient management of energy sources, especially renewable ones in a multivalent configuration or in a combination of renewable source and conventional source.
The study was carried out in a laboratory currently equipped with the multivalent renewable energy system (solar thermal system with tiltable collectors, photovoltaic system, reversible heat pump) combined with a conventional heat source (woodchip boiler, recuperation unit, condensing gas boiler, thermal storage, control units).

Aim of the research

The aim of the project was to explore SMART methods to increase the energy efficiency of multivalent systems based on RES. This goal should be achieved by implementing a combined model that is monitored and controlled by intelligent management systems. Furthermore, the results obtained should be specified in terms of environmental impact in terms of reducing the consumption of traditional (fossil) energy sources and help define future development trends in the use of renewable energy sources and their combinations in public buildings.

Achieved results

For example, the model of cogeneration unit, which enabled non-destructive monitoring of the flue gas pathways with regard to the production of pollutants was created. The algorithm for evaluating the combustion process was based on the elemental composition of the fuel and flue gas analysis. The results of the measurements, as well as the simulations, have led to the identification of the possibility of installing another flue gas exchanger in the flue gas path, which has been shown the efficiency of CHP - combined heat and power production. In the research, we have also looked at the possibility of eliminating the stagnation of thermal systems. The advantage of our proposed system is the complete automation of the management and the independent decision making of the system according to the current conditions. The system selects the most suitable operating variant at a given moment and no user intervention is required. The main objective of the following study was to determine the possibilities and conditions of decentralised combustion of non-hazardous municipal waste in a decentralized manner. Based on our results, we can draw the following conclusions: An addition of 20–30% of MSW to the fuel mixture resulted in an improvement of in the operating parameters of the combustion process. The addition of 50% of MSW leads to undesirable effects during the combustion process due to the different physics of the combustion of MSW and wood chips. At a concentration of MSW in the fuel of more than 30%, the emission limits cannot be met.

Benefits for practise

Based on the results obtained, the models and algorithms were applied under real laboratory conditions. Special attention was paid to the optimisation and verification of the experimental results and their dissemination for the conditions of energy processes based on renewable energy sources. The research results were published in prestigious foreign scientific and professional journals.

Fig. 1. / Solar system and woodchip boiler in the laboratory RSE

Fig. 2. / Combined wind-solar power station: 1 – Darier rotor, 2 – Savonius rotor, 3 – supporting structure, 4 – photovoltaic converters, 5 – control cabinet with rechargeable batteries.

Fig. 3. / Simulation solution for the flue gas model

Fig. 1

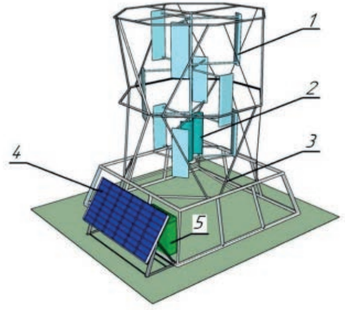

Fig. 2

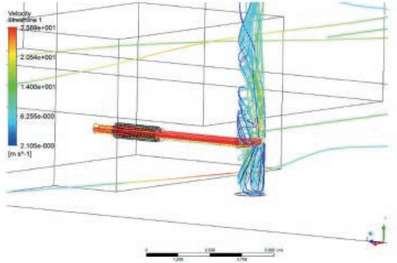

Fig. 3

Modular Development System for Control of Power Plant Units based on DCS.

Principal investigator
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Applicant organisation
Technical University of Košice
- Faculty of Electrical Engineering and Informatics
Term of solution
7/2017 — 6/2020
Budget from agency
242 515 €
Project ID
APVV-16-0206

Research subject

The project is focused on development and implementation of a prototype of a universal emulator for energy systems which form the basis of apparatuses for industrial production and consumption of electrical energy in power plants, heating plants and large industrial plants. Such a tool allows the user systematic and rational design of energy plants (e.g. small hydro and thermal power plants, heating plants, etc.), which guarantees effective creating of quality implementation projects (i.e. in a short time, with high degree of the implementation reliability and at low cost) for such energy apparatuses and cost savings at their concrete implementation. Universality and scalability of the emulator is provided by its implementation on the basis of the industrially produced DCS system. The main subjects of the development within the project there will be: models of individual energy sub-systems, their verification by experimentally obtained data, realization of parameterized emulator program modules, their visualization and verification of the emulator prototypes for control of a small hydropower plant.

Aim of the research

The main goal of the project is to design and implement a technical tool for the design and control of power plants, i.e. modular development system of power plant units based on a selected decentralized control system, the so-called DCS. Given the financial possibilities of this challenge, it is specifically planned to build a HW emulator for a small hydropower plant (hereinafter referred to as MVE), develop its corresponding software and experimentally verify it on real data obtained by measurements on a specific technology.

Achieved results

The main result of the project is a prototype "Emulator of energy systems based on decentralized system (DCS) from Siemens Company" (Fig.1). The emulator is currently located in the laboratory of EnergoControl s.r.o., Pri plynárni 2, Košice. This company is a future customer of the results of the project solution on the basis of the Contract on the future contract no. 25/1040/2016 – ATYP.

Benefits for practise

The benefit of the energy systems emulator is a significant optimization of project work in the design of SHPPs and a significant reduction in the implementation time of such projects directly in industrial practice. The expected savings in the implementation of a MVE complex order in terms of design and implementation of electrical parts and control using the emulator are about 30% -40% of time and financial costs.

Fig. 1 / Implemented MVE emulator hardware.

Fig. 2 / The structure of realised MVE software.

Fig. 1

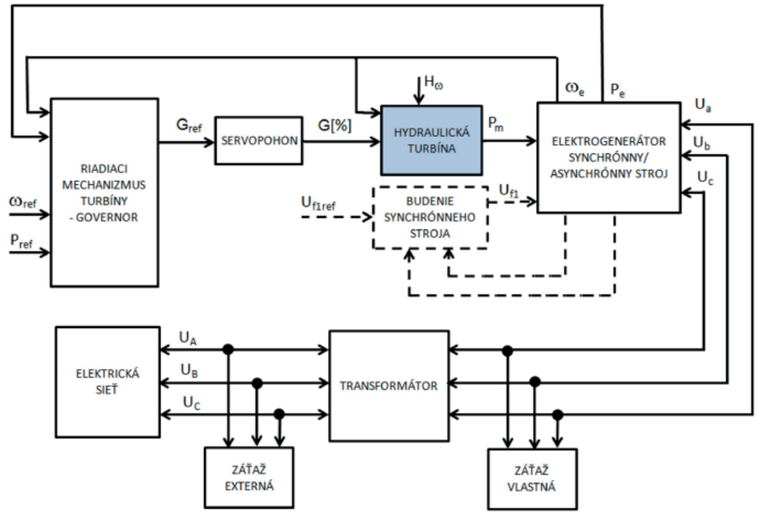

Fig. 2

Knowledge-based approaches for intelligent analysis of big data

Principal investigator
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Participating organisation
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Term of solution
7/2017 — 12/2021
Budget from agency
154 913 €
Project ID
APVV-16-0213

Research subject

The subject of the research was intelligent methods enabling the processing and analysis of big data in a broader knowledge context that describes and characterizes such an environment. We focused not only on big data of a static nature but also on dynamically data streams changing over time, which can be represented by data from the operation of various types of critical network infrastructures, data from social networks, or from various networks of sensors and smart devices.

Aim of the research

The main goal of the project was the design and verification of new adaptive methods for analyzing big data in a dynamically changing environment, which are able to extract new knowledge and integrate it with the knowledge model of the environment. In doing so, we focused on several target application domains, each of which has specific requirements, as well as data types and other properties.

Achieved results

Within this project, we achieved several significant results, from which we select the most important, along with their benefits for the practice. In the project, an extended knowledge model was created and validated for the description of the context of the target task (domain knowledge) as well as the specification of data analysis goals and the description of the data analysis process itself (chaining of operators during preprocessing, use of algorithms and methods of data analysis, and description of the resulting data-analytical models). The created model has been verified for Industry 4.0, medicine, and electronic commerce, while it allows specifying the goals of data analysis from concepts that describe the data analysis process itself, including its steps such as data preprocessing, use of algorithms, and evaluation. This model also enables the mapping of concepts to existing technologies for data analysis in the R programming language environment, which leads to partial automation of the data analysis process.

Benefits for practise

As part of the use of domain knowledge for predictive modeling, we dealt with the analysis of dynamic data streams. The proposed methods were verified in the areas of IT security and energy. In the field of security analysis, a knowledge model was created for a better classification of attacks in the IT environment. In the field of energy, through detailed knowledge analysis and the use of various machine learning strategies, it was possible to design effective electricity consumption prediction models that combine multiple predictors and use original strategies to adapt their weights over time, so that the accuracy of the prediction does not decrease even when conceptual drift appears. Their benefits have been demonstrated in the prediction of time series of measurements of electricity consumption from smart meters. In the field of supporting intelligent analysis of medical data, we focused on descriptive and predictive data mining with the aim of identifying not only similar groups of patients but also key differences between them and subsequently applying personalized treatment procedures, the result of which will be more effective and higher quality healthcare. In the case of domain/expert knowledge entering the data analysis process, we focused on the interpretability and explainability of decision models created using algorithms and methods of machine learning or artificial intelligence. In practice, the created software system based on data analysis models is also directly usable for decision support in several medical areas.
In addition, we devoted ourselves to the use of machine learning methods and conceptual data analysis in text processing and information retrieval, with an emphasis on the processing of data streams from social media, the detection of disinformation and anti-social behavior of users. We also used deep learning and data visualization methods to support Astro/Geo data processing. The created models enable the detection of phenomena in the solar corona and in the Earth's atmosphere, or other classification tasks in this domain area.

Fig. 1 / Usage of the knowledge model for prediction.

Fig. 2 / Basic modules of the knowledge model for modeling data-analytical processes in the domain of Industry 4.0

Fig. 3 / The person's speech is transformed into text and the emotion contained in it is determined by an emotional model (classifier) using the knowledge context. The robot receives this information and uses it to decide on the choice of answer as well as movements appropriate in the given emotional situation.

Fig. 4 / Knowledge model for the network intrusion detection domain.

Fig. 5 / Architecture of the SCSS-Net deep neural network model that was designed and successfully used to segment various structures on the solar corona.

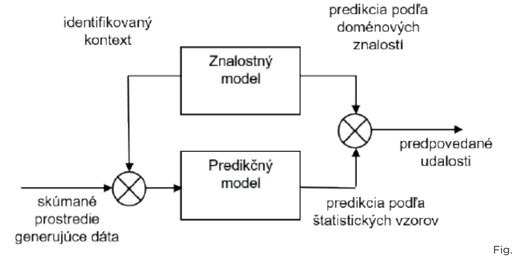

Fig. 1

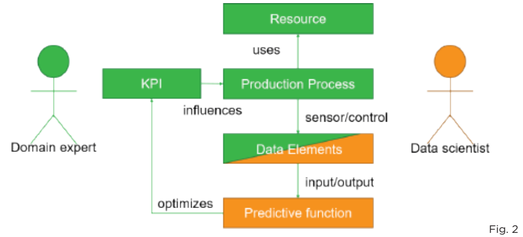

Fig. 2

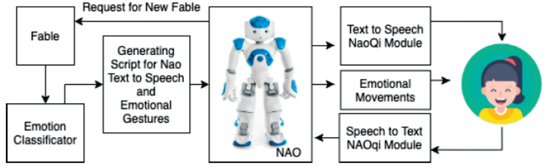

Fig. 3

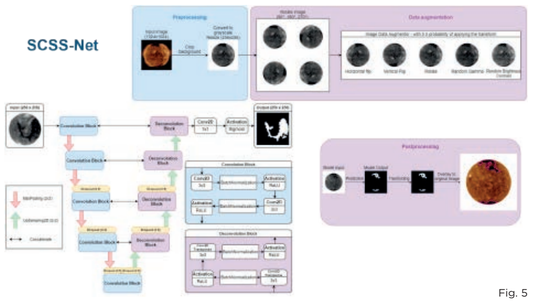

Fig. 5

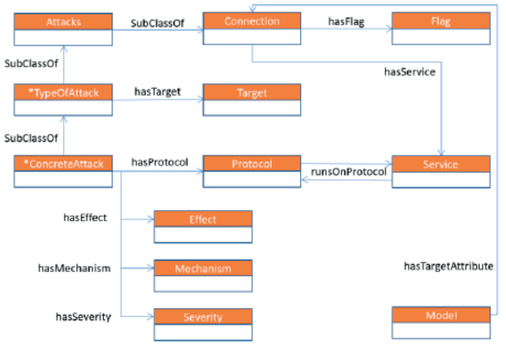

Fig. 4

Worldwide unique progressive methods of testing electrical cables for the needs of conformity assessment and verification of the constancy of their parameters as construction products

Principal investigator
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Participating organisation
VUKI a.s.
Term of solution
7/2017 — 6/2021
Budget from agency
200 000 €
Project ID
APVV-16-0223

Research subject

Reaction to fire class is a basic characteristic of an electric cable, quantifying its contribution to the development of a fire. Electric cable is classified into one of 7 classes (A_{ca}, $B1_{ca}$, $B2_{ca}$, C_{ca}, D_{ca}, E_{ca} or F_{ca}). The contribution to fire development increases from class Aca (no contribution to fire development) to Fca (significant contribution). In areas with high risk to people's lives and health during a fire (e.g. escape routes, hospitals, airports, tunnels, metro stations, school facilities, accommodation facilities, nuclear power plants, etc.), only electric cables can be installed in practically all developed countries with a certain minimum class of reaction to fire (e.g. in Slovakia, class B2ca is required for most of the mentioned premises). For this reason, manufacturers are obliged to measure and verify the fire reaction class of the manufactured cables at regular intervals (usually one year). These tests are usually very expensive. The costs of tests of one type of cable are reflected in the price of the final product the more the smaller volume of this type is produced. This fact puts small and medium-sized producers from Central Europe at a significant disadvantage compared to global producers, e.g. from the People's Republic of China. In addition, due to the amount of sample required to determine the reaction to fire class, these tests have a non-negligible impact on the environment. Therefore, the subject of the research was the creation of a new method of predicting the class of reaction to fire, which will be an order of magnitude less expensive and use a significantly smaller amount of sample (reduces the impact on the environment) than the methods known and used today.

Aim of the research

The goal of the project was to create a model for predicting the fire reaction class of an electrical cable from a photograph of its flame with an accuracy of at least 99%.

Achieved results

The main result of the project is a model enabling the prediction of the reaction to fire class of an electric cable from a photo of its flame with an accuracy of almost 100%. The entire process consisted of the design and construction of the test apparatus, the selection, adjustment, setup and training of the convolutional neural networks, the selection and tuning of the complementary discrimination algorithm. A key benefit is the ability to determine the reaction to fire class of an electrical cable at an order of magnitude lower cost and using a significantly smaller amount of sample compared to methods commonly used today. The accompanying output of the project is a model for determining the type of burning substance from a photograph of its flame. The key results of the project were published mainly in Martinka J, Rantuch P, Sulová J, Martinka F. 2019. Assessing the fire risk of electrical cables using a cone calorimeter. In: *Journal of Thermal Analysis and Calorimetry.* 2019. Vol. 135, Issue 6, pp. 3069–3083. DOI:10.1007/s10973-018-7556-5, Martinka J, Nečas A, Rantuch P. 2022. The recognition of selected burning liquids by convolutional neural networks under laboratory conditions. In: *Journal of Thermal Analysis and Calorimetry.* 2022. Vol. 147, Issue 10, pp. 5787–5799. DOI: 10.1007/s10973-021-10903-2 and Slovak Technical University in Bratislava. 2021. Method of checking the fire characteristics of electric cables. Martinka J, Rantuch P, Nečas A, Sulová J. Slovak Republic. Published patent application No. 22-2021. 20.12.2021. https://wbr.indprop.gov.sk/WebRegistre/Patent/Detail/22-2021.

Benefits for practise

The main benefit for practice is an order-of-magnitude reduction in the cost of assessing the reaction to fire class of electric cables while maintaining almost 100% accuracy. This benefit is essential for maintaining the competitiveness of small and medium-sized cable producers from Central Europe against global manufacturer. Another significant contribution to practice is the created method, which allows non-contact determination of the type of combustible substance during a real fire at a distance two orders of magnitude higher than the diameter of the fire. This contribution is essential especially for increasing the level of protection of the firefighting units involved and the protection of the population in the vicinity of the fire.

Fig. 1 / View of the test chamber with the sample before initiation

Fig. 2 / View of the test chamber with the sample during the test in the cone calorimeter.

Fig. 3. / View of the cone calorimeter with the test chamber.

Fig. 4. / Scheme of the test equipment a) photo camera; b) hood of the cone calorimeter; c) test chamber; d) tested cables.

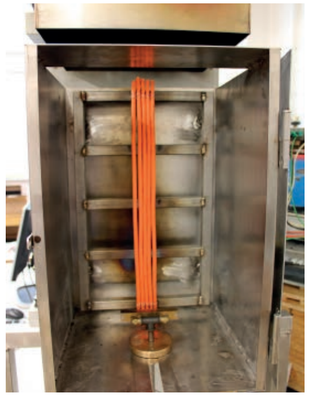

Fig. 1

Fig. 2

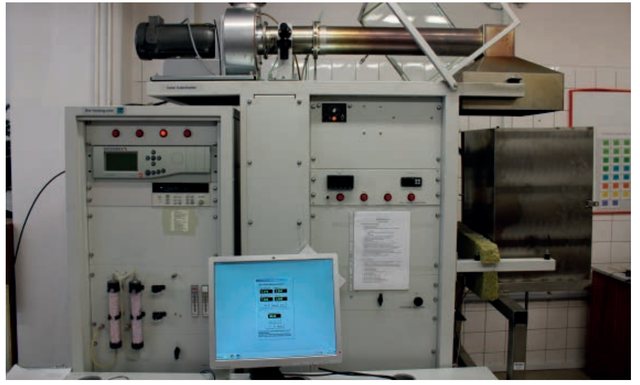

Fig. 3

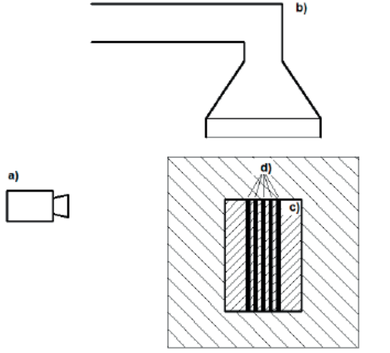

Fig. 4

Hybrid composite filaments for fused deposition ceramics prototyping

Principal investigator
doc. Ing. Marian Janek, PhD.
Applicant organisation
Slovak University of Technology in Bratislava - Faculty of Chemical and Food Technology, Department of Inorganic materials and Department of plastics, rubber and fibers
Term of solution
7/2017 — 12/2020
Budget from agency
203 036 €
Project ID
APVV-16-0341

Research subject

The main subject of the research was mastering the preparation of hybrid inorganic-polymeric materials suitable for 3D printing technology, which uses fused deposition of the materials. The proposed systems included the use of thermoplastic polymers in combination with a suitable ceramic filler usable for the preparation of green bodies by 3D printing such as: 1) hydroxyapatite, to produce personalized bone tissue replacements; 2) components of conventional and technical oxide ceramics, for the construction of complex ceramic structures e.g. prototypes of filters or catalyst carriers.

Aim of the research

The main goal of the project was applied research, in the field of preparation of hybrid ceramic composite materials, designed to acquire knowledge in the areas: 1) Identification of suitable thermoplastic polymers for the preparation of green bodies meeting the conditions of mechanical stability during their shaping by 3D printing; 2) Identification of suitable particles of ceramic raw materials for ceramic composites in the selected type of polymer; 3) Optimizing the amount of solid phase to achieve its required concentration in the polymer matrix and its processability using 3D printing; 4) Verification of the effect of solid phase on the behavior of produced bodies during controlled sintering; 5) Testing of the complex structures production from prepared composites such as green bodies, mimicking bones and generating specific skeleton models using 3D printing technology; 6) Monitoring and understanding changes in physical and chemical properties of prepared composite materials and made ceramic bodies; 7) Protection of intellectual property rights, results dissemination and popularization.

Achieved results

The processability of the filament in a 3D printer is affected by several important physical and chemical parameters such as: the temperature interval of the composite's usability, viscosity of the composite, the composite dosing rate, temperature range of the composite deposition, shape stability, minimum diameter of the nozzle for extrusion, microstructure of the ceramic after sintering, production process reproducibility etc. The production was verified with the industrial partner of the project by a field test production on the equipment used for the industrial filament productions. The printability of produced filament was further successfully tested on several commercial low-cost 3D printers e.g. LeapFrog, Pruša, Anet A8 and Raiscube. The high-temperature sintering of calcium-deficient hydroxyapatite used in the temperature range of 1100-1500 °C, showed new phases formation by X-ray powder diffraction only at temperatures above 1400 °C. The tests of contact toxicity showed that at certain temperature the presence of hydroxyapatite increases the number of cells observed. Comparison to the negative test revealed that the number of cells can be increased by 67%. As a part of the project, filament containing boron carbide as one of the hardest ceramic materials used in a neutron cancer therapy devices, was also successfully prepared and shaped by 3D printing for the first time.

Benefits for practise

The mullite ceramic composite has the potential to be used not only in hobby applications but also in rapid prototyping of ceramic parts, similarly to corundum composite for special applications. The production know-how was protected by filing a patent and an industrial design at the Industrial Property Office of the Slovak Republic. Commercial utilization of composite materials has been slowed down by the global Covid19 pandemic, the production is further negotiated. The research initiated submission of 12 projects within the Slovak Republic, including the Program for the Support of Excellent Teams of Young Researchers of STU, and one EU project. The results are currently being used in the ongoing Slovak Aid project. The 8 PhD students was involved in the project, 5 successfully defended their dissertations, 1 is about to finish her doctoral study, and 2 doctoral students interrupted their studies for the health reasons. Also, 4 bachelor students participated on the project topic. One of the main publication outputs published in the journal Applied Materials Today (SCI IF: 10.04) evocated the response of foreign media to the project research: https://3dprintingindustry.com/news/scientists-develop-more-affordable-ceramic-to- boost-hobbyist-3d-printing-185097/.

Fig. 1 / Model of the ceramic filter structure produced by 3D printing, A) cut-off from the structure of computer model; B) a real structure cut as printed on a 3D printer after sintering at 1400°C visualized by computer microtomography.

Fig. 2 / Examples of composite structures before sintering (green bodies) and after sintering at 1300°C (inset images in the lower right corner).

Fig. 3 / Selected hobby prints from mullite ceramics after sintering – *Terracotta warrior* printed with a height of individual layers of 100 µm – *Chess pawns* printed with a height of individual layers of 300 µm (height of the pawn green body in the middle approx. 3 cm).

Fig. 4 / Numbers of 3T3 NIH mice dermal fibroblasts observed after 72 hours in nutrient solution and contact with hydroxyapatite (HAp) sintered at temperatures 1100-1500°C (left) – negative control in nutrient solution without and in the presence of sterile gauze, positive control after soaking the gauze in 20 % SDS solution; studied cells proliferating on the surfaces of HAp test bodies observed under an optical microscope (right).

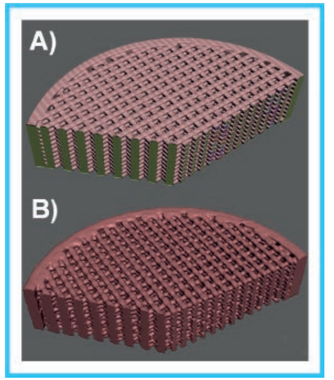

Fig. 1

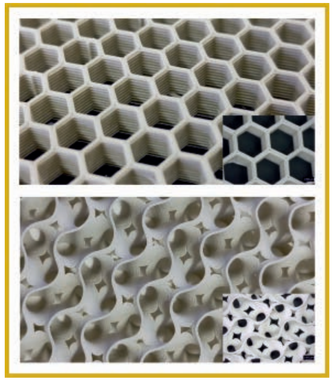
Fig. 2


Fig. 3

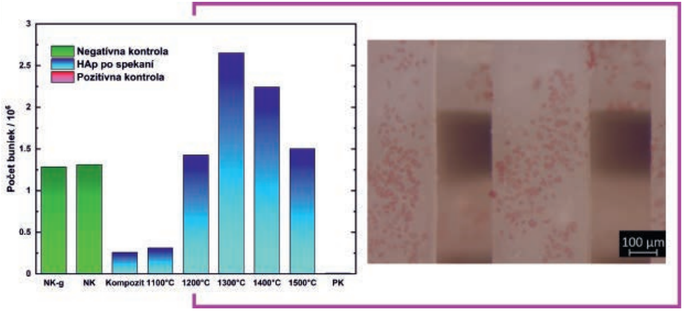

Fig. 4

The utilization of innovative technology for repair functional surfaces of mold casting dies for castings in automotive industry

Research subject

From the point of view of economic efficiency of production, high demands on the quality of die-castings intended for the automotive industry, saving of materials and energy, the increase of technical durability of mould parts and cores for die-casting of aluminium alloys is highly topical. The high cost production of new mould parts reduces the efficiency of production and thus the competitiveness of domestic producers in the European market in the field of subcontractors for the automotive industry. The applied research project was aimed at increasing the technological durability of mold parts and cores for die-casting of aluminium alloys intended for the automotive industry.

Aim of the research

The aim of the project was to increase the technological durability of moulds for casting aluminium alloys under high pressure by using innovative technologies for the restoration of mould functional surfaces. Both conventional and unconventional methods of welding were used for the renovation of mould parts - MAG CMT (Cold Metal Transfer) technology, TIG (Tungsten Inert Gas) technology, PTA (Plasma Transferred Arc) technology, laser welding technology and MIG (Metal Inert Gas) technology. FEM analysis of the stress-strain state of the mould parts was used to identify the critical areas of wear. By comprehensive material analysis, tribological tests of the clads in dry sliding friction conditions, corrosion tests of the clads in 1M NaCl solution and simulation of realistic stress conditions of the clads by immersion in AlSi8Cu3 aluminium alloy melt at 680±20°C, information on the durability of the clads with respect to the original material of the mould shaped parts was obtained. The machinability of the clads was controlled by the wear of the cutting inserts.

Achieved results

Based on the experimental results, the highest quality was achieved by the clads made using a laser beam with Dievar additive material. From the point of view of high-pressure casting technology, the mould filling and removal of the castings from the mould after 6000 cycles were analogous to those of the new mould parts. The renovated and coated mould parts were maintained in further operational tests. An innovative method of surface treatment of mould and core mould parts was developed, which consisted in local intensive heating of the surface by laser radiation in the interval of recrystallization temperatures without material melting with finishing grinding to the desired geometry of the mould surface with deposition of duplex PVD coatings chemically stable at the casting temperatures of aluminium alloys. Local intense laser surface heating procedures were applied to a group of cores with final duplex PVD coating with nACRo4 and AlCrN3 coatings. A control group of shape and dimensionally identical cores was PVD coated with duplex nACRo4 and AlCrN3 coatings. Both groups of cores were tested under real operating conditions of high pressure casting of aluminium alloys after assembly into the moulds. The cores with the treated surface are in service tests and meet the required surface quality criteria for commercial castings. The application of innovative renovation technologies has ensured a longer lifetime of the cores while reducing the technological downtime associated with the replacement of worn cores. The solution of the project provided original results and application recommendations for foundries in the production of die-castings intended mainly for the automotive industry. As a result of the project, a patent application has been registered - Method of surface treatment of mould parts and cores for casting of aluminium alloys.

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Participating organisation
Institute of Materials Research Košice
Term of solution
7/2017 — 12/2020
Budget from agency
247 957 €
Project ID
APVV-16-0359

Benefits for practise

The results of the project solution and application recommendations can be used for foundries in the production of die-castings intended mainly for the automotive industry. The proposed renovation layers and surface treatment using laser radiation with simultaneous deposition of PVD coatings will increase the technological durability of mould parts (inserts) and cores. The technological lifetime is limited mainly by the quality requirements imposed on castings cast under high pressure. With high demands on the surface quality of high-pressure castings and shape complex castings, it is economically advantageous to renovate the mould parts (inserts). Longer core life reduces the technological downtime associated with the replacement of worn cores.

Fig. 1 / Crack around the ejector and core cavity.

Fig. 2 / Heat flux density and temperature field. Aluminium - mould time 1.5×10^{-3}

Fig. 3 / Dievar - immersion in AlSi8Cu3 melt, 680°C, 300 min, formation of intermetallic phases

Fig. 4 / Dievar - laser clads. Immersion in AlSi8Cu3 melt, 680°C, 300 min, formation of intermetallic phases

Fig. 5 / Dievar – MIG clads. Immersion in AlSi8Cu3 melt, 680°C, 300 min, formation of intermetallic phases.

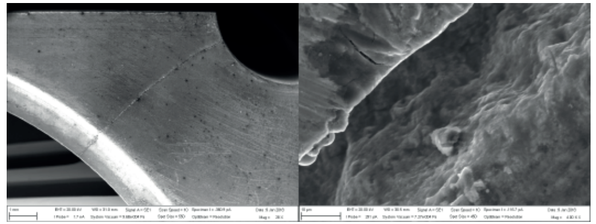

Fig. 1

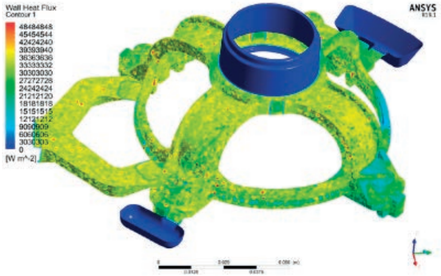

Fig. 2

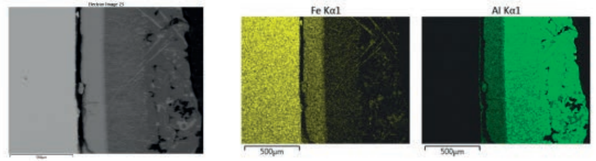

Fig. 3

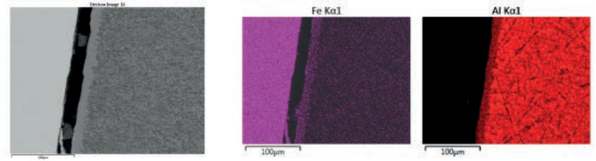

Fig. 4

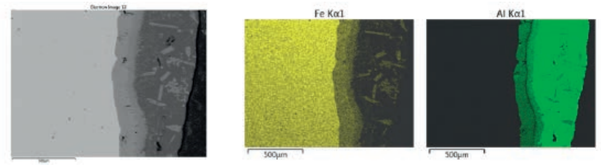

Fig. 5

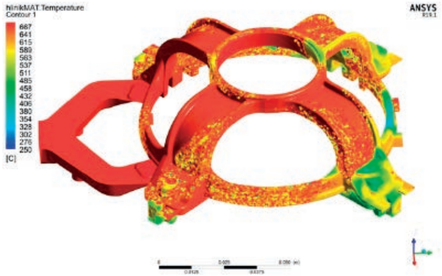

Fig. 2

Elimination of sticky contaminants in the processing of waste paper

Principal investigator
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Pulp and Paper Research Institute, jsc.
Term of solution
7/2017 — 6/2021
Budget from agency
248 000 €
Project ID
APVV-16-0409

Research subject

There are various sources and types of impurities in waste paper, such as adhesives, resins, fillers, wet strength agents and soluble colloidal materials, coatings, and latexes. These agents, in combination with each other, create sticky impurities, the so-called micro and macrostickies. The removal and elimination of micro and macrostickies from the pulp suspension during the processing of waste paper is the subject of the project solution. This can be achieved by improving the separation of sticky impurities from waste paper already by applying new highly effective chemicals in the pulping process, with a subsequent agglomeration of micro and macrostickies into larger particles using selective chemicals with a high affinity for sticky dirt.

Aim of the research

The goal of the presented project is to propose optimal procedures for the removal and elimination of sticky impurities in the processing of waste paper, based on the study of the effects of different types of chemicals in a laboratory and operating conditions. The proposed solution for the removal and elimination of micro and macrostickies will ensure the order of lower content of sticky impurities in the suspension of waste paper, and a higher quality of the produced water substance, which will increase the runnability of paper production and ensure better time utilization of processing lines.

Achieved results

Based on the results of laboratory and operational tests in the paper processing line in MT Žilina, a technology for eliminating sticky impurities was proposed to improve the operation. The proposed technology consists of the application of three components:

- Prodeink Extra –to improve the release of undesirable substances from waste paper during pulping of waste paper;
- Prodeink AS10 –to improve the separation of sticky impurities, fillers and other undesirable substances during flotation and to control foam during flotation;
- Hydrobent PAI –to improve the elimination and separation of sticky impurities in the process of flotation and fine sorting.

Operational tests of the application of the above-mentioned technology confirmed high efficiency in the elimination of sticky impurities and increased efficiency of the collection line in ash removal of the paper pulp suspension and increased efficiency in achieving the resulting whiteness of the produced water substance. In the production of VL5 water suspension, the line efficiency of the elimination of macrostickies increased from 60% to 90%, in the production of VL1 from 39% to 86%, in the production of VL0 from 34% to 92%, and in the production of VL0, the elimination increased from 27% to 94%. The application of the new technology also had a positive effect on the line's efficiency in removing fillers from the water substance suspension, while the efficiency increased in the range of 0.4-0.9% and in increasing the whiteness of the water substance in the range of 0.4% to 2.5% ISO.

Benefits for practise

The proposed technology was already used in the collection paper processing line during the project. The increase in the quality of water suspensions produced in MT Žilina, from the point of view of the content of sticky impurities, caused a decrease in the number of breaks in the production of sanitary papers, a decrease in the number of shutdowns and an increase in the runnability of the PS2 paper machine. The lower amount of sticky impurities increased the time utilization of the rewinding and the productivity of the processing lines. By applying the proposed technology, costs were reduced by 7.25 EUR/t of produced paper. With the production of 40,000 t/year of sanitary paper based on waste paper, this represents savings of 290,000 EUR/year.

Fig. 1 / Sources of micro and macrostickies in the processing of waste paper.
Fig. 2 / Scheme of the flotation process of waste paper.
Fig. 3 / Laboratory flotation device.
Fig. 4 / Comparison of macrostickies content at the output of the waste paper processing line.

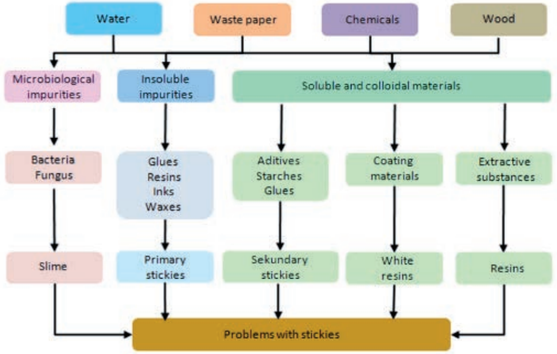

Fig. 1

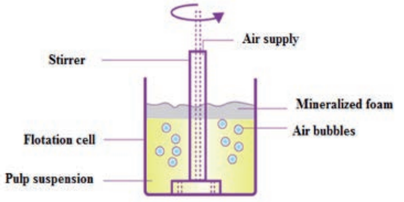

Fig. 2

Fig. 3

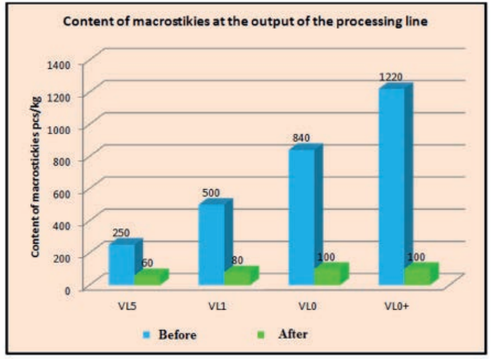

Fig. 4

Innovative system for testing logistic processes by using simulation and emulation

Principal investigator
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Applicant organisation
University of Žilina - Faculty of Mechanical Engineering
Participating organisation
Asseco CEIT, a.s., Žilina
Term of solution
7/2017 — 6/2021
Budget from agency
243 082 €
Project ID
APVV-16-0488

Research subject

The project focused on the design and creation of system for testing logistics systems with the use of simulation and emulation models of new production/assembly devices. The created system uses the connection between virtual model of device which is not installed yet and real logistics. System uses virtual form of device for informing the real logistics about the need to import input material into the process alternatively export of finished parts out of process. System was built-up as a support tool for design of changes in the production mainly with the help of testing capacity utilization logistics and determination of bottlenecks of the whole production and logistics system in the future.

Aim of the research

The main aim of the project was to design innovative system for testing logistics processes in industrial organisations based on the connection of real and virtual world with the help of computer emulation.
Partial aims of the project:
• Proposal of the procedure for accurate and fast creation of simulation and emulation models of production, assembly and logistics facilities.
• Proposal of standardised procedures for creation of communication between real logistics elements of system and virtual emulation models.
• Proposal of statistics module for data collection and evaluation of capacity utilisation of logistics facilities with the use of automated data collection.
• Integration of all modules to uniform system of testing.
• Building of pilot workplace for testing virtual models and real logistics and evaluating of procedures at this workplace.
• Testing of the whole system in conditions of company Nemak Slovakia in newly built hall for high pressure casting.

Achieved results

The output of the project is a complex modular system for testing logistics processes, which is made up of the following basic modules:

1. Library - internal library of standard elements of the production and logistics system (models of machines, handling equipment, transport and storage elements, elements of building systems).
2. Designer - module for designing production systems in 3D environment.
3. Basic planner - module for setting basic parameters of logistics.
4. Logistic planner - module for logistics system designing (logistics networks designing, transport relationships definition, connecting objects to logistics networks, analysis, optimization and visualization of material flows, management of logistics assets, parameterization of transport flows, design of milk runs, etc.).
5. VR mode - interface allowing the user to view the projected scene in a virtual environment.

The complex modular system was verified in two phases:
1. Verification under pilot workplace conditions: The test worplace represented a production system with two positions that were operated by an AGV truck. The experimental proposal used RFID and RTLS systems for data acquisition and a control system with a global control method.
2. Verification in conditions of industrial practice: Testing of the system was carried out in the conditions of Nemak Slovakia in a newly constructed high-pressure casting hall. The physical environment for the verification of the proposed system consisted of 48 production facilities, 4 AGV trucks and 5 man-operated logistics facilities. The virtual environment in the emulation model contained the existing state of the physical environment and additional manufacturing and logistics facilities that were planned to be implemented within a 2-year time horizon. The functionality of the system was verified through 80 series of experimental tests.

Using the emulation tests in the conditions of Nemak Slovakia, it was verified that the proposed system allows to test the logistics without the need to deploy all production equipment and thus prevent errors before their physical deployment and production start.

Benefits for practise

The final output of the project is a fully functional innovative system for testing logistics processes using simulation and emulation, which has undergone a two-stage verification and is ready as a final product for deployment in industrial practice in order to increase the speed and quality of the design of future production and logistics systems based on a comprehensive assessment of the mutual interactions between these two key business systems. The proposed system is generally applicable in the manufacturing sector and in particular in the engineering, metallurgical and automotive industries.

Fig. 1 / Schematic diagram of the system for testing logistics processes.
Fig. 2 / Pilot workplace for testing virtual models and real logistics.
Fig. 3 / Architecture of pilot workplace intelligent control system.
Fig. 4 / Design of a system structure for verification of logistic processes using emulation in conditions of industrial practice.

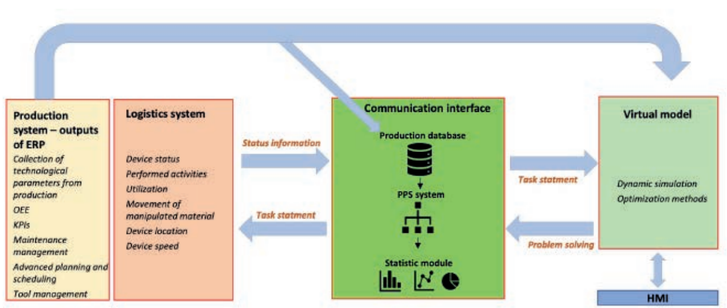


Fig. 1

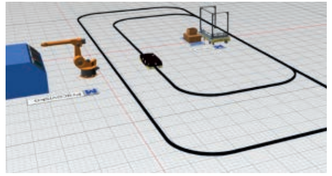
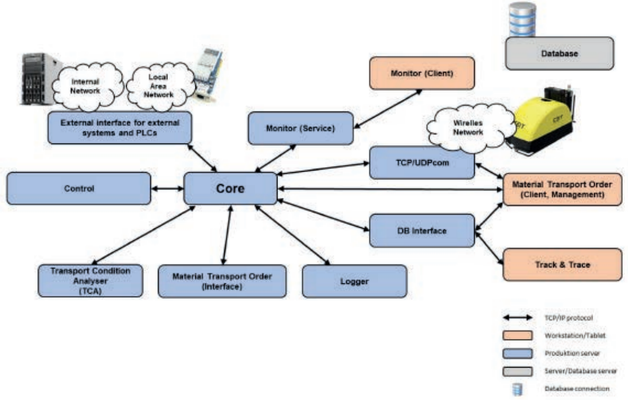


Fig. 2



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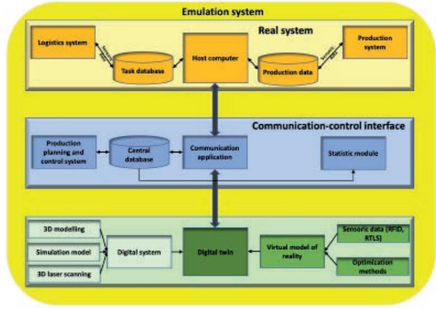

Fig. 4

The short-term prediction of photovoltaic energy production for needs of power supply of intelligent buildings – predicon

Principal investigator
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Faculty of electrical engineering and information technology
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Term of solution
7/2017 — 12/2020
Budget from agency
249 931 €
Project ID
APVV-16-0505

Research subject

The project under the acronym PREDICON dealt with the development of a method for very short-term forecasting of the power of a photovoltaic power plant (PVE) with a time range of the forecast in the range of 5 to 30 minutes. An algorithm using the analysis of sky image data was designed for the prediction of the intensity of the solar radiation flow, as the main factor influencing the PV power output. The prediction of the movement of clouds taken at the installation site of the PV plant also uses local weather information.

Aim of the research

The main goal of the project was the research, design and development of a system for short-term forecasting of the performance of a photovoltaic power plant, which would be based on the use of data obtained at the installation site. The proposed solution is based on modern approaches and methods including computer vision, IoT (Internet of Things) and DLNN (Deep Learning Neural Network). This solution was primarily designed for sophisticated power consumption management of smart buildings with PV.

Achieved results

As part of the project solution, a main weather station for a photovoltaic power plant (Predicon-Main) and a network of compact IoT stations (Predicon-Cube) were designed for local weather monitoring and collection of meteorological data at the level of the urban agglomeration. Also, a custom version of the camera unit (Predicon-Cam) was developed for capturing 360° of the sky constructed from readily available electronic components and 3D printing. Subsequently, a system was designed for short-term forecasting of the performance of a photovoltaic power plant using a neural network, and a system for the detection and description of dynamic parameters of objects appearing in the sky and the creation of a 3D reconstruction algorithm. For the purpose of short-term forecasting of photovoltaic power plant performance, an advanced IoT weather station system and a system for semantic sky analysis including motion tracking, evolution and cloud classification were designed. A system for local estimation of solar radiation transmissivity was also created and a prediction model of electricity consumption using a neural network was designed. Finally, a system was created for general air quality monitoring and a mobile application (Predicon Weather Forecast) was developed to make the data available to the public.

As part of the solution, 2 industrial designs were granted:
- PUV 44-2020 Advanced IoT weather station.
- PUV 163-2020 Equipment for area measurement of air quality.

Benefits for practise

The main result of the project was the creation of a hardware platform with software tools for monitoring and prediction the performance of a photovoltaic power plant using IoT, computer vision and artificial intelligence technologies. The results of the project will find application as part of smart building systems in the short-term management of the power supply of its components or the prediction of the availability of electricity from its photovoltaic power plant when powering electric cars. Since the creation of an IoT network of sensors is part of the solution, the results can be used for short-term weather prediction, as an early warning subsystem in the area covered by IoT weather stations (e.g. a city) or as a public service in the form of data sharing in the monitored area, including air quality monitoring.

Fig. 1 / Database samples, a) clear, b) partly clear, c) partly cloudy, d) cloudy.

Fig. 2 / Automatic semantic segmentation of the sky, a) original sky image, b) manually annotated sky, c) annotated sky by neural network.

Fig. 3 / Camera system prototype, a) primary sensing platform with photovoltaic panels and weather stations, b) secondary sensing platform for compiling a 3D sky map, c) dome camera, d) air conditioning unit.

Fig. 4 / Prototype of a compact IoT weather station, a) installed PCB, b) detail of the assembled weather station, c) set of weather stations, d) location of the station.

Fig. 5 / Courses of predicted and actual performance of the test panel, a) day with the worst prediction, b) day with the best prediction.

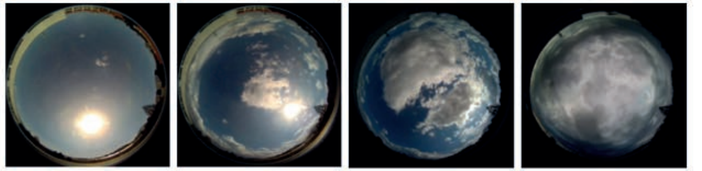


Fig. 1

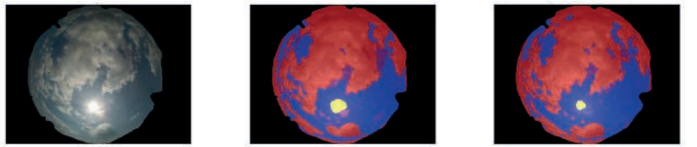
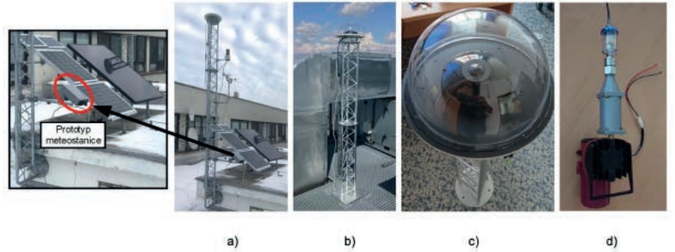


Fig. 2



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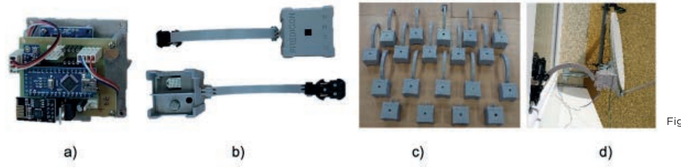

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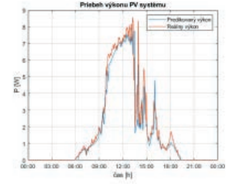
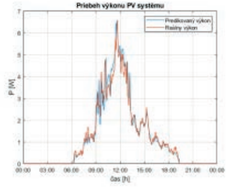
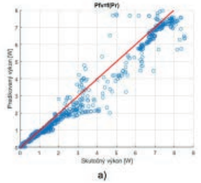


Fig. 5





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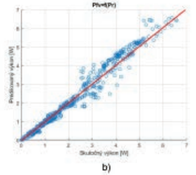

Research on increasing of availability of supply networks formed by static power converters

Principal investigator
Ing. Zdeno Biel, PhD.
Applicant organisation
EVPÚ a.s.
Term of solution
7/2017 — 12/2020
Budget from agency
250 000 €
Project ID
APVV-16-0574

Research subject

As part of the applied research project, the possibilities of increasing the availability of power semiconductor converter systems were addressed. The research was mainly focused on the issue of creating DC and AC parallel systems in railway applications, through which it is possible to achieve the required increase in reliability and availability of such systems by using the principle of redundancy. In order for the individual converters of the parallel system to reliably work together and achieve the required parameters, it was necessary to propose appropriate control strategies ensuring appropriate power sharing and suppression of unwanted circulating currents. In addition, the project dealt with the design of the concept of innovative power semiconductor converters, focusing on the possibility of operation in such parallel systems.

Aim of the research

Design and development of control algorithms and regulatory structures of inverters and chargers enabling their connection to a common bus and forming parallel systems to increase their reliability and availability. Design of electric circuits and mechanics of converters with the possibility of implementing proposed control software enabling parallel cooperation. Achieving stable operation of inverters and chargers implemented in parallel systems of auxiliary converters of rolling stock.

Achieved results

The proposed control strategy for the parallel cooperation of inverters allows connecting several modules through a common bus and thus creating parallel systems of different sizes, which brings the power variability. In case of sufficient power reserve of the system, its operation will not be interrupted even in the event of failure of any inverter, since the supply of the required power to the common bus will be ensured by the remaining inverters. This will achieve a substantial increase in the reliability and availability of such systems. The created control software was implemented in inverter modules built into railway auxiliary converters. An experimental setup with four inverters connected to a common bus was constructed, where the achieved parameters were verified in both static and dynamic modes. The achieved power distribution between the individual converters was within ±4% tolerance. For use in DC power supply systems, a control algorithm was also designed to enable parallel operation of chargers using CAN serial bus communication. The advantage of such a solution is that there are no drops in the output voltage. The proposed control software was tested and debugged on an assembled parallel system with four chargers. The measurements confirmed the reliable operation of such a system with an accuracy of current sharing up to ±5%. On the basis of the performed tests, the possibility of achieving an uninterruptible power supply in case of failure of one or more converters of the parallel system was also confirmed.

Benefits for practise

Two new types of converters have been designed and manufactured for application in rolling stock with implemented developed control software enabling parallel cooperation of the converters. The control algorithm for parallel cooperation of three-phase inverters was used in the auxiliary converter intended for powering auxiliary drives of a railway car with a nominal power of 30 kVA. This converter enables the formation of a parallel systems by connecting to the common three-phase bus of the train, ensuring the suppling of the electrical appliances of the individual wagons. The developed software enabling the parallel cooperation of chargers was applied to the designed prototype of the auxiliary converter intended for urban railways rolling stock. This converter is used as a central power source of an electric multiple unit. Two converters are installed in the train, whose chargers with a nominal power of 10kW are connected in parallel and together provide power for 24V DC appliances and the charging of the batteries. Each of the chargers is able to provide the full required power for the entire vehicle. This solution ensures 100% redundancy. An uninterrupted supply of voltage for appliances and battery charging is ensured even in the event of a failure of one of the chargers. In normal operation, the chargers are loaded to a maximum of half of their rated power, which brings a substantial increase in the lifetime and reliability.

Fig. 1 / Measured waveforms of the output currents during parallel operation of four inverters. C1 – C4 - phase U currents of individual inverters, F3 - total load current.

Fig. 2 / Auxiliary converter to power auxiliary drives of the rail wagon enabling parallel cooperation by connecting the outputs of the inverters to a common bus.

Fig. 3 / Measured currents during testing of parallel cooperation of four chargers. C1 – C4 – output currents of individual chargers, F3 – total load current.

Fig. 4 / Auxiliary converter for urban railways rolling stock and charger module with implemented software for parallel cooperation during testing.

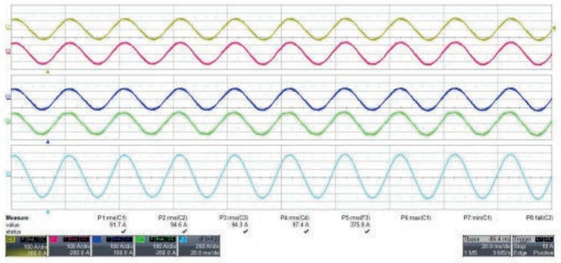

Fig. 1

Fig. 2

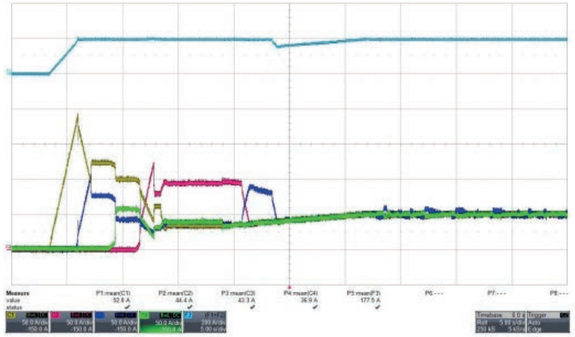

Fig. 3

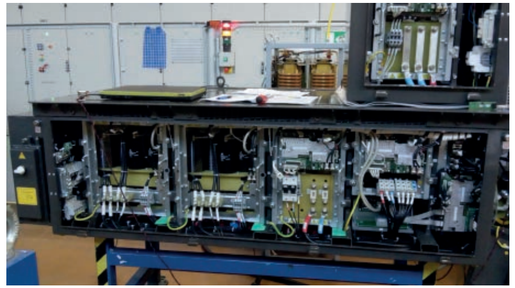

Fig. 4

Flexible system for Internet of things with use of SMART sensors

Principal investigator
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Applicant organisation
POWERTEC s.r.o.
Participating organisation
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- Faculty of Electrical
Engineering and Information Technology
Term of solution
7/2017 — 10/2020
Budget from agency
249 897 €
Project ID
APVV-16-0626

Research subject

The Internet of Things (IoT) topic covers a wide range of technological and IT inputs, including the development of semiconductors, sensors, software, big data processing and the development of applications for everyday use. The development of the issue of research and design of hardware units, such as sensor points, control, and monitoring elements, creates space for applying the achieved results with high added value in the industry. An example of application in the safety area can be the monitoring of children, bicycles, or animals. Furthermore, also in the field of healthcare, for example the use of bio-monitoring systems or in the field of the environment, such as monitoring harmful substances in the air, measuring, and spreading dust or smog. An important sector of the application of IoT issues is also the field of industry and production, moving towards - Industry 4.0.

Aim of the research

The main goal of the project was the development of the design of sensor systems as part of the Internet of Things (IoT), the preparation of models of sensor systems connectable to the IoT network and the development of a methodology for the design and implementation of sensor systems, to be used in key areas like environmental protection, safety, or health care. Among the key goals of the project was also the building of a workplace with an IoT orientation, which will significantly support the further involvement of both project partners in European research consortia with the potential for rapid use of application results in practice.

Achieved results

The designed prototype of the sensor system consisted of a main module on which the basic blocks and connectors for additional modules are located. System management and data processing are provided by a microprocessor, which can work in energy-efficient modes, but also provides sufficient performance to process a larger amount of data. These can be stored in the internal memory of the microprocessor, or, if necessary, on a memory card or other memory element connected via the SPI bus. Basic environmental sensors are integrated on the main PCB, which, depending on the application, can be used as the main data source or to compensate for environmental effects on other sensors. The communication module is connected via a universal connector and one of 3 buses (I2C, SPI, UART), thanks to which most standard wireless networks used in IoT can be used for communication. An external battery, solar system or AC adapter can be used as a power source. Each additional module connected via the RS485 bus has its own control system and power management, while these are subordinate to the main module. Additional modules also ensure data processing. Additional sensory modules developed later can be connected in this way, while the functionality of the main module does not have to be adapted.

During the implementation of this project, in addition to the prototype of the environmental modular sensor platform, prototypes of other IoT devices were also created:
a) Pet tracker: a device used to locate a pet, especially a dog or cat, if the animal is lost. Battery life is up to two months under normal operation.
b) Electronic seal: a device for securing the electricity meter against tampering. It detects a break in the sealing optical fiber, has a built-in vibration sensor, which also detects mechanical handling of the device.
c). SMART thermometer: provides innovative measurement and recording of body temperature. Once attached to the patient's body, this device enables continuous remote monitoring of physiological parameters.
During the project implementation 3 WoS/Scopus category articles, 6 contributions at international conferences and 13 contributions at domestic conferences were published. Also, two patent applications have been submitted, 5 utility models and one registered design have been approved.

Benefits for practise

- The proposed environmental modular sensor platform became the basis for the development of other types of modular IoT devices,
- Development of three smaller IoT device prototypes,
- Development of a methodology for the design and preparation of IoT systems,
- Building a workplace oriented to the field of IoT technology,
- Acquired knowledge and experience used in the preparation of new national and European grants,
- The selected equipment prototypes were further optimized in the post-project period and their actual deployment is expected in 2023.

Fig. 1 / Basic parameters in the specification of the end IoT device.

Fig. 2 / Methodology for the development of the Internet of Things system.

Fig. 3 / Prototype of the main system module with communication module and additional sensor.

Fig. 4 / Prototype of pet tracker.

Fig. 5 / Prototype of SMART thermometer.

Fig. 6 / Prototype of electronic seal.

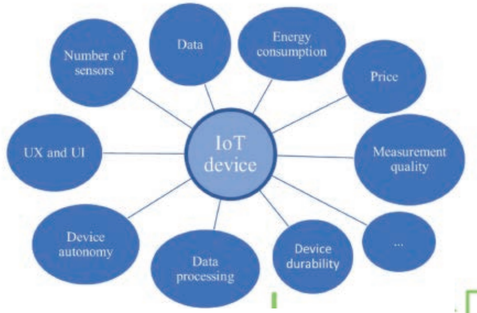

Fig. 1

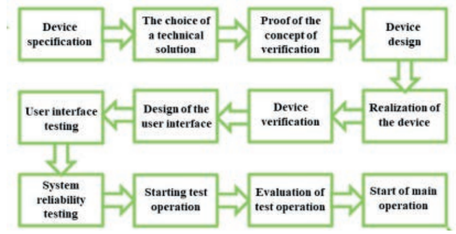

Fig. 2

Fig. 6

Fig. 4

Fig. 5

Fig. 3

MEDICAL SCIENCE

Identification and validation of signalling pathways associated with circulating tumor cells in breast cancer

Principal investigator
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Applicant organisation
Comenius University, Faculty of Medicine
Participating organisations
Cancer Research Institute, Biomedical Research Center, Slovak Academy of Sciences, Institute of Molecular Biology, Slovak Academy of Sciences, Comenius University in Bratislava - Faculty of Natural Sciences
Term of solution
7/2017 — 12/2021
Budget from agency
249 624 €
Project ID
APVV-16-0010

Research subject
Circulating tumor cells.

Aim of the research
1. To identify signaling pathways in primary tumor associated with CTC in primary breast cancer patients
2. To validate candidate signaling pathways on tumor tissue microarray
3. To establish animal model for CTC detection
4. To validate candidate signaling pathways on animal model for CTC

Achieved results
Circulating tumor cells (CTC) are an independent prognostic factor in both primary and metastatic
breast cancer. CTCs represent a heterogeneous population of tumor cells and play a crucial role in the metastatic cascade and in tumor progression in a process called self-seeding. The presence of CTC in the peripheral blood is a marker of the metastatic ability of the tumor. Within the project, we managed to prove for the first time the prognostic significance of CTC with EMT phenotype as well as the prognostic significance of circulating nucleosomes in primary breast Ca. We focused on several pathways potentially associated with CTC, without observing an association between CTC and circulating nucleosomes, MMP9 (as opposed to MMP1). We observed an association between tumor infiltration by tumor infiltrating lymphocytes (TIL) and prognosis in CTC_EMT-positive patients, on the other hand, we did not observe an association between CTC and TIL, which supports the hypothesis of their independent prognostic significance. We also found an association between TILs and selected plasma cytokines. We observed an association between the patient's prognosis and the systemic inflammatory index (SII) and created a combined model to predict the prognosis of primary breast Ca by a combination of CTC and SII. We also found an association between circulating cytokines and PD-L1 expression in tumors of patients with primary breast cancer, we did not observe an association between CTC and PD-L1, however, PDL1 was prognostic only in patients with CTC_EMT. We identified somatic mutations in the BRCA1 and 2 genes in the tumor as mutations positively associated with CTC with an epithelial subtype, but we were unable to identify an association between drug history and the presence of CTC. We compared gene expression in primary breast Ca between patients CTC_EMT + and CTC-. 1202 genes were identified by RNA-seq. Among the most prominent candidates are several genes from the keratin family (KRT5, 14, 17) and claudins (CLDN8, CLDN9).

Benefits for practise
- The prognostic significance of CTC with EMT phenotype was demonstrated for the first time
- The prognostic significance of circulating nucleosomes in primary breast Ca has been demonstrated for the first time.
- We found an association between MMP9 and several clinicopathological characteristics in primary breast Ca.
- We observed an association between tumor infiltration by tumor infiltrating lymphocytes (TIL) and prognosis in CTC_EMT-positive patients.
- We observed an association between the patient's prognosis and the systemic inflammatory index (SII) and created a combined model to predict the prognosis of primary breast Ca by a combination of CTC and SII.
- We found an association between circulating cytokines and PD-L1 expression in tumors of patients with primary breast cancer.
- We identified somatic mutations in the BRCA1 and 2 genes in the tumor as CTC-positively mutations with an epithelial subtype.

Experimental data generated by the project are the basis for further research in this

Fig. 1 / Kaplan–Meier estimates of probabilities of disease-free survival according to CTC_EMT status (n = 427), Hazard ratio=0.42, 95%CI=0.22-0.78, p=0.0003.

Fig. 2 / Kaplan–Meier estimates of probabilities of disease-free survival according to CTC_EMT status in different molecular subtypes A) Luminal A, B) Luminal B, C) HER2 positive, D) Triple negative.

Figure 1

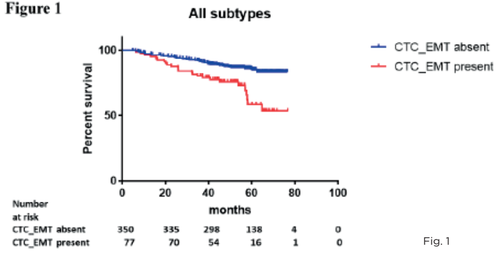

Fig. 1

Figure 2A

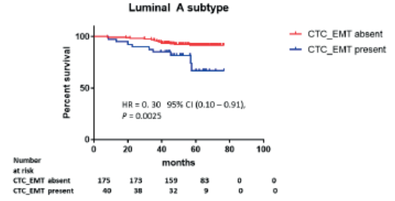

Figure 2B

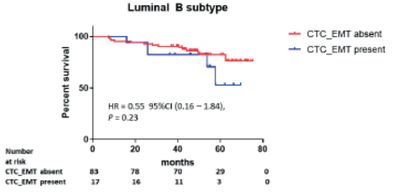

Figure 2C

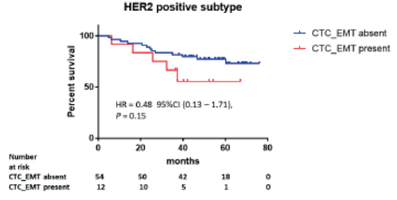

Figure 2D

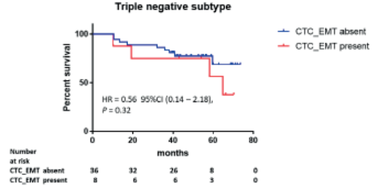

Fig. 2

Specific laboratory monitoring of the platelet reactivity in patients with acute myocardial infarction treated by novel P2Y12 receptor antagonists.

Principal investigator
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Applicant organisation
Comenius University in Bratislava,
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Term of solution
7/2017 — 9/2021
Budget from agency
248 420 €
Project ID
APVV-16-0020

Research subject

The dual antiplatelet treatment (DAPT) is together with the urgent revascularization basis of the therapy in patient with acute myocardial infarction with elevations of ST segment (STEMI). DAPT is based on the combination of treatment with acid acetylosalicylic (ASA) and P2Y12 platelet receptor antagonists. Interindividual variability of the platelet response on clopidogrel is well known, while a high platelet reactivity on P2Y2 antagonists treatment is associated with higher risk of reccurent thrombotic complications after percutaneous coronary intervention (PCI). Novel oral P2Y12 antagonists (prasugrel and ticagrelor) exhibit stronger and more predictable inhibitory effect and achieve also significantly better clinical results that was confirmed in trials TRITON-TIMI 38 and PLATO. Nevertheless, the reports appeared repeatedly in the literature about HTPR even on the treatment with these drugs which can predispose to the thrombotic complications after PCI. On the other hand the extremely strong platelet inhibition due to novel P2Y12 antagonists can increase the risk of bleeding complications in patients with STEMI.

Aim of the research

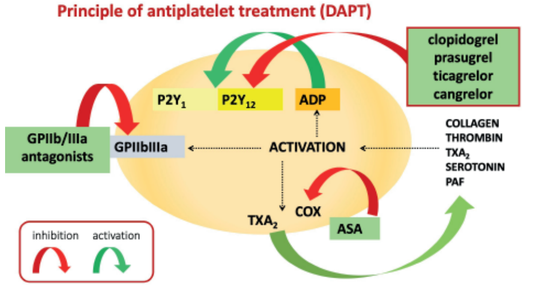
Aim of the project was to identify using a wide spectrum of laboratory methods the individuals with unsafisfactory or extremely strong platelet inhibition among patients with acute STEMI treated with novel P2Y12 antagonists and discover the prevalence of high on treatment platelet reactivity (HTPR) in this patient group. Additional issue was focused to an explanation of the effect of clinical factors on the platelet reactivity during treatment and mutual relationships between platelet reactivity and risk of ischemic or bleeding complications.

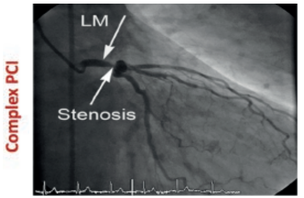
Achieved results

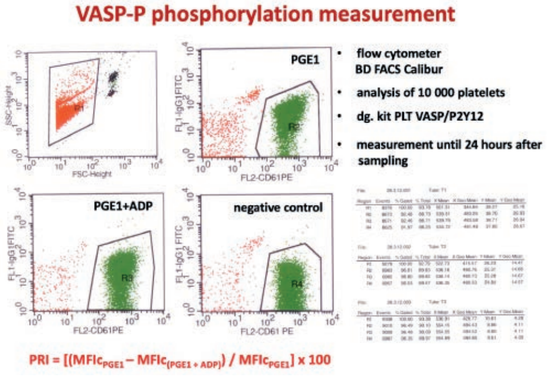
We followed up in the project mainly patients with acute STEMI undergoing PCI and focused to possible HTPR on DAPT with novel P2Y2 antagonists. In pilot prospective study there were 46 patients with STEMI (23 patients on combination ASA and ticagrelor and 23 patients on ASA and prasugrel). The effect of P2Y12 antagonist treatment was evaluated before urgent PCI after load dose of P2Y12 antagonist and 1st day after PCI and administration of maintenance dose of P2Y12 antagonist. There is interesting result of the study that the required therapeutic response wasn´t achieved in samples of the patients with STEMI after the P2Y12 novel antagonist (prasugrel/ticagrelor) load dose prior PCI, which was measured by method VASP-P using flow cytometry. In our study there was verified the unsuficient response (HTPR) on the treatment with novel P2Y12 antagonists which can led to serious adverse events, e.g. stent thrombosis after PCI. Except of patients with acute STEMI we followed in the project also 71 patients undergoing complex elective PCI due to the left coronary artery lesion, the coronary bifurcation or severe calcification lesion. We measured in these patients HTPR on the treatment with P2Y12 antagonists. 39 patients were on clopidogrel, 28 patients on ticagrelor and 4 patients on prasugrel. Among 20 patients with HTPR on 1st day after PCI there was 17 patients on clopidogrel and 3 patients on ticagrelor. One month after PCI there was 18 patients with HTPR, including 16 patients on clopidogrel and 2 patients on ticagrelor. In total, 3 patients after complex PCI had the in-stent thrombosis (4,2%), that is 2-fold higher incidence compared to the unselected patients undergoing PCI. HTPR on the treatment with P2Y12 antagonists measured by VASP-P was verified 1 day after PCI in 34% of patients and HTPR was present in 30% of patients 1 month after PCI. Our results suppose that HTPR on the P2Y12 antagonists (especially clopidogrel) treatment in patients undergoing the elective complex PCI is associated with markedly increased risk of the early onset in-stent thrombosis and need of revascularization.

Benefits for practise

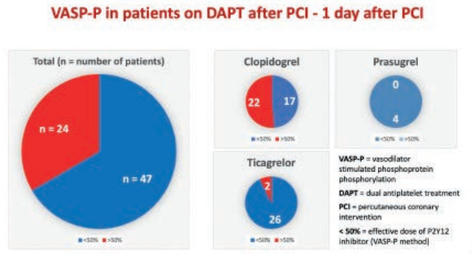
In our cohort of patients undergoing PCI due to STEMI or coronary stenosis there was an incidence of HTPR on the treatment with P2Y12 antagonists in 30-34% of patients even 1 month after PCI. Application of such specific monitoring into clinical practice in selected patients with STEMI after PCI could be of benefit for health and quality of life in these patients and also it could have a significant economic gain throught the reduction of costs on the treatment of additional thrombotic complications (e.g. reduction of costs on the treatment of coronary stent rethrombosis and STEMI recurrence) or also throught the reduction of costs on the treatment of serious bleeding.

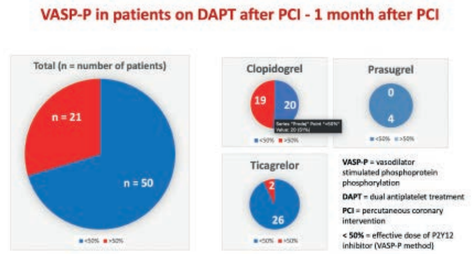






- flow cytometer BD FACS Calibur
- analysis of 10 000 platelets
- dg. kit PLT VASP/P2Y12
- measurement until 24 hours after sampling





The role of microRNAs in breast cancer: biological significance, targeted molecules and signalling pathways

Principal investigator
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prof. MUDr. Pavol Žúbor, PhD., DrSc., MBA, FRSM (2017-2018)
Applicant organisation
Biomedical Centre Martin, Jessenius Faculty of Medicine in Martin, Comenius University in Bratislava
Term of solution
6/2017 — 12/2021
Budget from agency
222 149 €
Project ID
APVV-16-0021

Research subject

The project focused on the role of miRNA molecules as the modern biomarkers in breast carcinogenesis and regulation mechanisms of the disease progression.

Aim of the research

The main aim of the project was to clarify aspects of the biological aspects of the miRNAs in etiopathogenesis, development, clonal evolution, metastatic progress and relapse of breast cancer. The project had also focused on the integration of multidisciplinary clinical-genomic-metabolomic strategy in the management of patients, which could lead to improved treatment options and quality of life.

Achieved results

As experts from the field of mammalogy, animal experiments, biologists, geneticists and bioengineers participated in the project, it´s outputs brought wide range information. The basic research focused primarily on clarifying the biological characterization and function of miRNAs:

- We determined a miRNA panel signature with a higher or lower expression in subphenotypic stratification of breast cancers by analyzing 2549 miRNA molecules.
- We optimized in the cooperation with the Italians and subsequently performed the detection of plasma miRNA expression using microarray method followed by qPCR validation.
- A study of miRNA expression in plasma was conducted through independent analyses, which resulted in a KEGG systematic analysis of the processes and signaling pathways of detected by miRNAs.
- Based on GWAS studies, we analyzed several genetic variants with moderate penetrance, identified statistically relevant genetic variants, and created a breast cancer risk model containing only variants with high discriminative power.
- We assigned specific methylation signatures to molecular subtypes of breast cancer according to the level of CpG methylation of tumor suppressor genes. Analyzes also pointed to differences according to hormonal status, estrogen and/or progesterone receptor expression.
- Metabolomic analyzes identified changes in the metabolomic profile in the context of cell metabolism, proliferation and tumor growth.

During the project implementation, the team of researchers wrote several scientific and review articles, scripts and several students had completed dissertation theses. At the same time, the interaction with the medical doctors from the Martin University Hospital was strengthened and foreign collaborations were established. The implementation of the project brought new research opportunities, challenges, as well as other scientific questions that require expert explanations.

Practical benefits

The implemented project brought new knowledge about the biological nature of miRNA molecular mechanisms. The results of metabolomic and genetic analyzes could be integrated into the diagnostic, operative and postoperative adjuvant management of the breast cancer patients after the successful validation on an independent and larger cohort, as a supplement to already existing examination methods. Monitoring the individual dynamics of miRNA expression could also be a starting point for targeted and personalized therapy.

Fig. 1 / miRNA expression and hierarchical clustering by Z-score normalized values of log2 expression. Columns – cancer and control samples, lines – miRNAs.

Fig. 2 / PLS-DA (right) analysis of binary system breast cancer / controls, algorithm fed by relative concentrations of metabolites determined by NMR spectroscopy in deproteinized blood plasma samples.

Fig. 3 / Methods applied to inhibit cancer progression by dysregulation of mRNA translation by miRNA.

Fig. 4 / CpG methylation analyses of promoter region of the ESR1 gene by pyrosequencing.

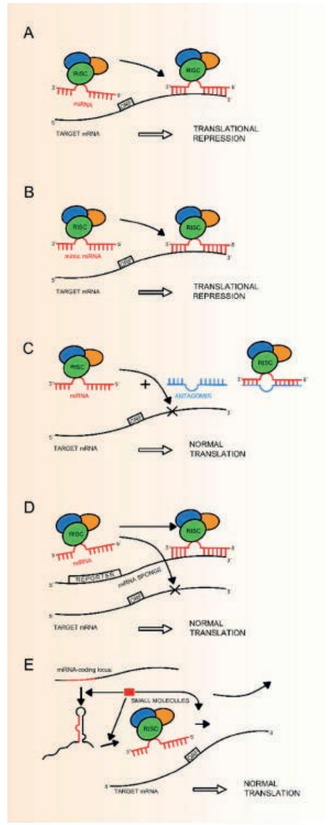

Fig. 3

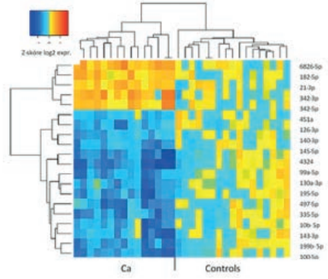

Fig. 1

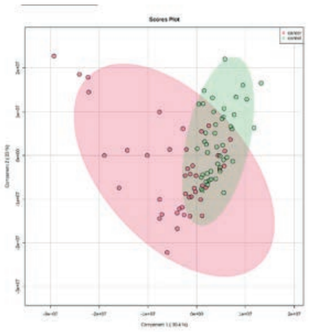

Fig. 2

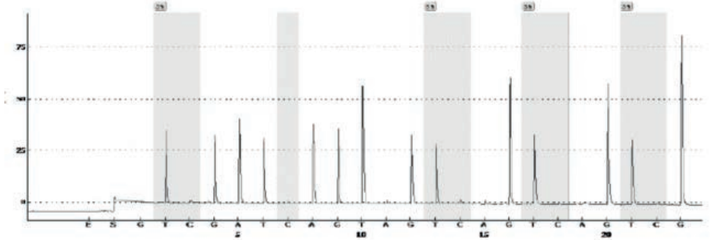

Fig. 4

Mechanism of the mesenchymal stromal cell-induced tolerance to antitumor treatment and targeted therapeutic intervention in the breast cancer cells

Principal investigator
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Applicant organisation
Biomedical Research Center SAS
- Cancer Research Institute
Participating organisation
REGENMED s.r.o.
Term of solution
7/2017 — 12/2021
Budget from agency
249 998 €
Project ID
APVV-16-0178

Research subject

Chemoresistance to conventional cytotoxic drugs used in breast cancer patients results in disease relapse, progression and dissemination. There are many intrinsic mechanisms in breast cancer cells contributing to refractoriness to chemotherapeutic agents. Tumor microenvironment surrounding the tumor cells, which is composed of many types of non-malignant cells and extracellular proteins, significantly affects drug responses by soluble-factor mediated and cell adhesion-mediated drug resistance. The interactions between the tumor cells and TME blunt the cytotoxic effect of genotoxic drugs thus substantially negatively affecting treatment efficiency. Mesenchymal stromal cells as one of the TME components represent relatively resistant cell population actively recruited and engrafted in the TME. The exposure to chemotherapeutic drug alters their phenotype thus substantially affecting tumor cell behavior.

Aim of the research

The project is focused on analysis of chemotherapy-triggered changes of tumor microenvironment, on unraveling of the molecular mechanism by which MSC blunt the response to chemotherapeutic agents and induce tolerance in otherwise intrinsically sensitive tumor cells and on tha analysis of MSC effects on tumor growth and metastatic potential.

Achieved results

Analysis of individual MSC secretory phenotype after the exposure revealed changes in production of pleiotropic cytokines, chemokines and growth factors (1). Exposure of the MSC to DOX in our study was associated with increased secretion of SDF-1α, IL-32, THBS-1, DPPIV and uPAR when compared to unexposed MSC. Paclitaxel exposure resulted in decreased production of CXCL5, endoglin, Dkk-1 and increased production of IL-32. We have observed also influenced proliferation and secretory phenotype of tumor cells in co-culture. Histochemical tumor xenograft analysis revealed increased invasive potential of tumor cells co-injected with DOX-MSC or PAC-MSC (2) and also the presence of nerve fiber infiltration in tumors (3) what was associated with poor prognosis and metastatic rate in breast cancer. Chemotherapy-exposed MSC have also influenced angiogenic potential in the model of chorioallantoic membrane. Angiogenesis also plays an important role in tumor cell dissemination. We have shown that the co-culture of tumor cells and chemotherapy-exposed MSC with subsequent application on CAM membrane resulted in higher angiogenesis as well as dissemination of tumor cells in case of triple-negative breast cancer cells (4). However, the exact molecular mechanism responsible for chemotherapy-induced effects needs to be properly examined, our data suggest that neoadjuvant chemotherapy could alter otherwise healthy stroma in breast tissue into misled tumor-promoting and metastasis favoring hostage. Targeting the tumor microenvironment and its complex net of signals, therefore, raises hope that the standard therapy might not fail in the end, but accomplish the curative purpose.

Fig. 1 / Cytokine determination using the Proteome Profiler Human XL Cytokine Array Kit revealed that DOX exposure was associated with increased secretion of SDF-1α, IL-32, THBS1, DPPIV and uPAR in DOX-MSC compared to unexposed MSC. PAC exposure resulted in decreased production of CXCL5, endoglin, Dkk-1 and increased production of IL-32.

Fig. 2 / Representative pictures of Ki-67/VIM immunohistochemically stained xenografts' periphery showed increased ability of tumor cells to invade into the surrounding stroma in xenografts formed by MDA cells co-injected with DOX- and PAC-MSC.

Fig. 3 / Polyclonal antibody identifying nerve tissue (against S100 protein) stained nerve structures cross-section area in the tumor (indicated by arrows) and in the adjacent adipose tissue up to 2 mm from the tumor surface. Increased nerve infiltration of tumors was observed in co-cultures with DOX-/PAC-MSC.

Fig. 4 / Evaluation of angiogenesis in co-culture of MDA-MB-231+MSC (unexposed or DOX-/PAC-exposed) on CAM by fractal analysis through quantification of fractal dimension (Df). We observed significantly higher vascular growth in DOX-/PAC-MSC co-culture compared to unexposed MSC co-culture and MDA only group. Co-cultures were growing on the CAMs in the area defined by a silicone ring. MDA cells co-cultured with DOX-MSC and PAC-MSC formed micro-metastases (indicated by arrows) outside that silicone ring.

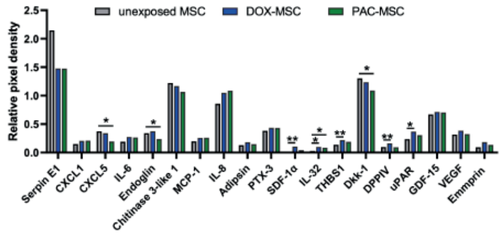

Fig. 1

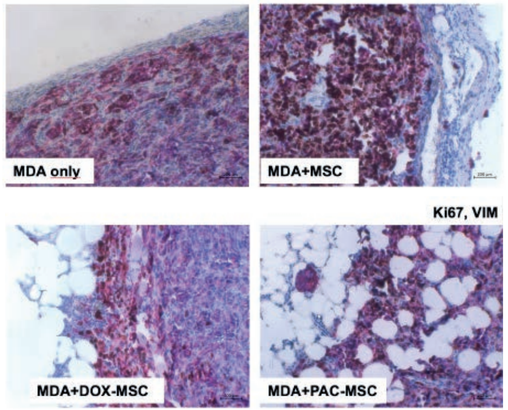

Fig. 2

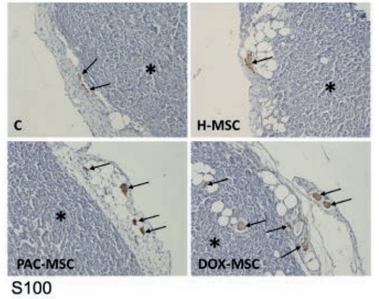

Fig. 3

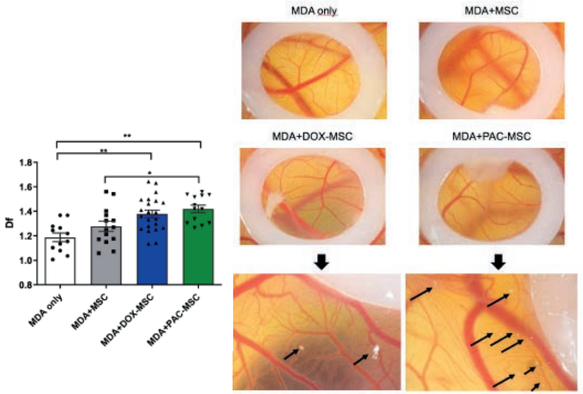

Fig. 4

Research of magnetic forms of iron in development of cardiovascular diseases and behavioural disorders

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Term of solution
7/2017 — 12/2021
Budget from agency
249 000 €
Project ID
APVV-16-0263

Aim of the research

The first aim of the project was to determine the effect of aging on iron (Fe) metabolism, its magnetic properties and subsequent metabolic and functional changes in the cardiovascular system and brain in rats with different genetic predispositions to hypertension. The second aim was to determine the effect of exogenously administered Fe in the form of biocompatible superparamagnetic nanoparticles based on iron oxides on the blood pressure regulation, the function of the heart and blood vessels in conditions of normotension, hypertension and acute increase in blood pressure (BP) due to stress.

Achieved results

We obtained several original results about changes in Fe metabolism during aging and depending on the genetic predisposition to high blood pressure (hypertension) in rats. We found the greatest differences in Fe content in young spontaneously hypertensive rats (SHR) compared to normotensive Wistar-Kyoto (WKY) rats. We did not confirm the assumption of the development of age-related behavioural changes due to the increased accumulation of Fe in the tissues of WKY or SHR rats, as the magnetic properties of the tissues of both genotypes were similar in old age. In rats that were the offspring of SHR dams and WKY sires, so-called borderline hypertensive rats, the elevated BP was reduced by oral administration of the cocoa flavanol (-)-epicatechin. This was associated with a decrease in saturation magnetization of blood, probably due to a decrease in Fe concentration, and also with increased nitric oxide (NO) production in the aorta and heart (1).
We also obtained original results on the effect of two types of superparamagnetic magnetite (Fe_3O_4) nanoparticles in WKY and SHR. We found tissue-specific effects of biocompatible Fe_3O_4 nanoparticles coated with polyethylene glycol (Fe_3O_4@PEG, Figure 1a) especially on magnetic properties of the liver (Figure 1b), selected biochemical, metabolic and genomic parameters in the heart, blood vessels, brain, kidneys, liver and plasma and also on properties of the red blood cells (2,3,4,5). Important is the finding of a significant effect of acute stress (associated with an acute increase in BP) in normotensive rats on the biodistribution of intravenously applied Fe_3O_4@PEG, vascular wall function and on increase in the production of NO in the liver, which led to a delayed decrease in their resting BP value (2). When Fe_3O_4@PEG were administered in the same manner to SHR rats, a single infusion under resting conditions had no effect on their BP. However, repeated administration of a higher dose of Fe_3O_4@PEG decreased BP also in SHR under resting conditions, which was associated with increased NO production, increased expression of the gene for inducible nitric oxide synthase in the liver and with increased deposition of Fe_3O_4@PEG in the liver and aortic vascular wall (Figure 2) (3).
For SHR, we also used another type of nanoparticles in which polyethylene glycol was bound with alendronate (Fe_3O_4@PEG-Ale, Figure 3) to stabilize the Fe_3O_4 nanoparticle coating. We showed that Fe_3O_4@PEG-Ale nanoparticles had no negative effects on BP, vascular wall function and the red blood cell properties (4).

Benefits for practise

The results may be important for clinical practice, pointing to the fact that high BP, both chronically and acutely (e.g. as a result of acute stress), affects the tissue distribution and biological effects of iron oxide nanoparticles, which can induce a sudden decrease in BP in individuals with otherwise normal BP value. The results thus point to the fact that in the case of administration of iron oxide nanoparticles, for example as contrast agents in MRI or in other medical applications, it is necessary to pay attention to the patient's BP values before and after their infusion.
The results of the project can also be used in further experimental research. We developed and published a method for the preparation of biological samples, quantification and differentiation of biogenic Fe naturally present in blood and in the tissues from Fe originating from Fe_3O_4@PEG using SQUID magnetometry (6). This method makes it possible to identify small amounts of iron originating from Fe_3O_4@PEG, which could not be distinguished from Fe naturally found in tissues or blood using common biochemical or histochemical methods. The method can be used in both solid and liquid biological samples at a temperature 300K (26.85°C). The method is significantly more efficient than commonly used magnetometric measurements at the temperature of 2K (-271.15°C), it is faster and less expensive.
By December 2021, the results of this project were published in a total of 18 publications (with an impact factor), mostly in journals in Q1 journals and they were cited more than 100 times.

Fig. 1
Figure 1a. Transmission electron microscope image showing a dispersion of Fe_3O_4 nanoparticles coated with polyethylene glycol. The size of the iron core of the nanoparticles was approximately 30 nm (6).
Figure 1b. Image showing the different magnetic properties of the livers from control normotensive rats (red line) and rats treated with polyethylene glycol-coated Fe_3O_4 nanoparticles (blue line) (6).

Fig. 2 / Electron microscope photographs showing the vascular wall of the aorta of Wistar-Kyoto (WKY) rats (2a) and spontaneously hypertensive rats (SHR) (2b) after repeated administration of Fe_3O_4 nanoparticles coated with polyethylene glycol. The figures document a significantly higher deposition of nanoparticles (indicated by the arrows) in the aorta in SHR, a model of human primary hypertension (3).

Fig. 3 /Image of a proton nuclear magnetic resonance (^{1}H NMR) spectrum of Fe_3O_4 nanoparticles coated with polyethylene glycol using alendronate (3a) and their scheme (3b) (4).

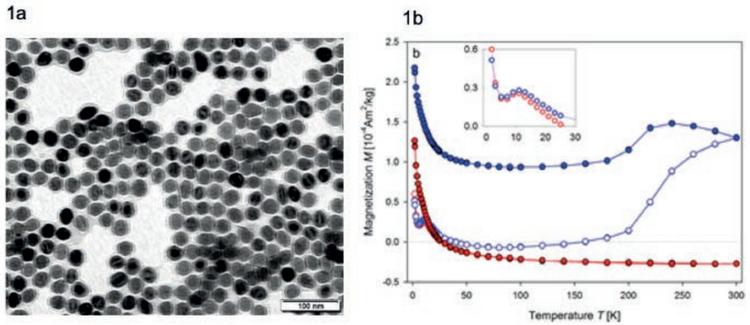

Fig. 1

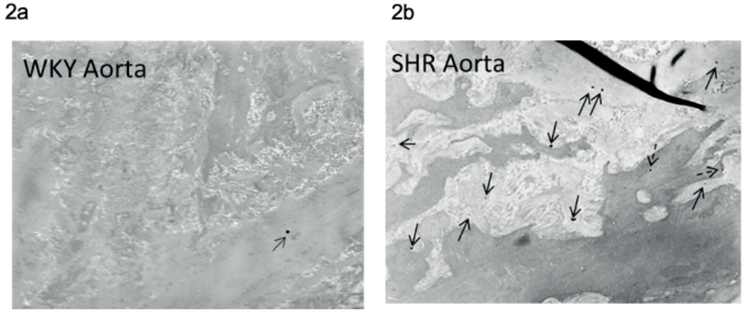

Fig. 2

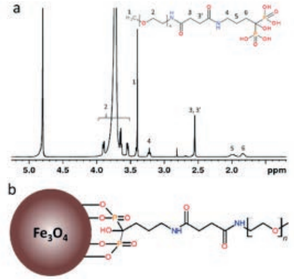

Fig. 3

Impact of comorbidity therapy on tumorigenesis and a role of the tumor microenvironment in this process

Principal investigator
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Term of solution
7/2017 — 12/2021
Budget from agency
249 055 €
Project ID
APVV-16-0343

Research subject

The coexistence of cancer and other accompanying diseases is very common, and their treatment can affect the outcome of anticancer therapy. Tumor microenvironment (TME) is very complex and organized. Tumor-associated protein carbonic anhydrase IX (CA IX) significantly affects TME and is among the best hypoxia markers. Epidemiological studies revealed a link between chronic stress and tumor progression. Findings that betablockers (BB) have antitumor effects support the hypothesis that β-adrenoreceptors (β-AR) may play an important role in tumor progression. 3D models naturally create gradients of O2, pH, nutrients. They simulate tumor mass more faithfully and can be used to predict the response of tumor cells to chemotherapy. Cardiovascular diseases (CVD) treated with BB belong to the most common comorbidities, so we monitored the effect of BB on the efficiency of chemotherapy.

Aim of the research

The main project goal was to investigate the impact of treatment of some comorbidities on antitumor therapy. We focused on: 1. Creating a 3D model integrating multiple components of tumor mass. 2. Investigation of the effect of BB on CA IX function and the composition of its interactome. 3. Monitoring the effect of chronic stress and BB therapy on cell invasiveness in 2D and 3D models. 4. Monitoring the effect of BB on the efficiency of chemotherapy. 5. Preparation of tumor organoids from primary tumor cells and their use for predicting response to chemotherapy.

Achieved results

CVD are often treated with BB, which compete with catecholamines for binding to β-AR. We proved that BB propranolol (PROP) reduces the ability of tumor cells to adapt to hypoxic stress and acidosis and it activates apoptosis (Fig.1). PROP reduces tumor cell migration and the level of β subunit of HIF1 regulating CA IX expression. By inhibiting PKA, PROP affects CA IX activity. We confirmed PROP effects in both 2D and 3D models of one- and 2-component spheroids. We observed an increase in CA IX level in cells resistant to 5FU, and a decrease in CA IX level and in the migration ability of these cells treated with PROP. In vivo, we showed a reduced growth of xenografts in mice pretreated with PROP, when PROP was administered after the appearance of xenografts, and a reduced growth of xenografts derived from 5FU-resistant cells after PROP administration (Fig. 2). We found specific interaction of anti-CA IX antibody conjugate and functionalized nanoparticles in a 3D model of colorectal (CRC) tumor cells and their penetration into spheroids. We proved the presence of hypoxia and CA IX in abdominal aortic aneurysms. We identified PIMT - a new interaction partner of CA IX and confirmed its presence in the metabolon in CRC tissues (Fig. 3). We found a significantly higher level of β2-AR and also a high level of CA IX in CRC samples. We found a lower level of the soluble form of CA IX in the plasma of patients stratified based on the use of betablockers. We introduced a method for preparation of tumor organoids (Fig. 4), which could be used for testing potential antitumor drugs and predicting the response to therapy.

Benefits for practise

Obtained results can be applied especially in clinical practice. CA IX is one of the best hypoxic markers and, due to its membrane localization, also a promising target for antitumor therapy. Results obtained by analyzing the binding and penetration of a specific antibody conjugated with functionalized nanoparticles inside CA IX-positive cells represent a promising approach for using such particles in targeted thermotherapy. The proof of hypoxia, the presence of CA IX in abdominal aortic aneurysms and the presence of soluble CA IX in the plasma of these patients open up possibilities for the use of CA IX not only in oncology but also in other diseases linked with hypoxia/ischemia. Information on the effects of PROP on tumor cells expressing β-AR leading to reduced ability of cells to adapt to hypoxic stress and acidosis indicate possible use of BB in antitumor therapy in combination with chemotherapeutics. Results of in vivo experiments showed the inhibitory effect of PROP on the growth of xenografts from cells resistant to 5-FU, which points to a possible application in the therapy of resistant tumors. The introduction of the methodology for preparation of tumor organoids provides a promising approach not only for the study and testing of potential therapeutics, but also a tool for use in personalized medicine.

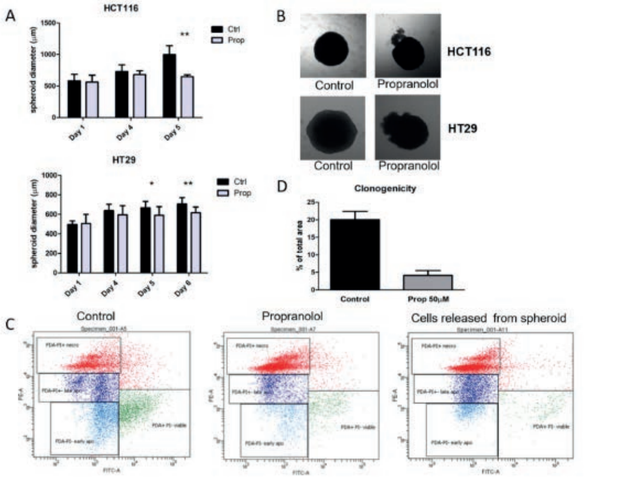


Fig. 1

Fig. 1 / Propranolol affects adaptation to hypoxic microenvironment, reduces spheroid growth and increases apoptosis in HCT116 and HT29 3D models. (A) Growth graph of HCT116 and HT29 spheroids over time, spheroids were cultured individually and measured regularly with a Zeiss Axiovert 40 CFL microscope. The graph shows the mean ± standard deviation of the measurements of the diameter of 7 spheroids (* str < 0.05), (** p < 0.01). (B) Representative images of HCT116 and HT29 spheroid morphology after 5 days of PROP (50 µM) treatment. (C) Flow cytometry results of live, apoptotic and necrotic cells of HCT116 spheroids. (D) Propranolol reduces the clonogenic potential of HCT116 spheroid cells.

Fig. 2 / Graph of the growth of xenografts formed from HCT116P50 cells adapted to propranolol (groupE-LT-P50 control) and treated with propranolol (groupD-LT-P50 PROP treated) and from HCT1165FU cells resistant to 5-fluorouracil (groupF-5FUresist-control) and treated with propranolol (skupG-5FUresist-Prop treated).

Fig. 3 / Results of GST-pulldown assay in different cell lines (a) and Proximity ligation assay (b) of interaction of CA IX and PIMT proteins.

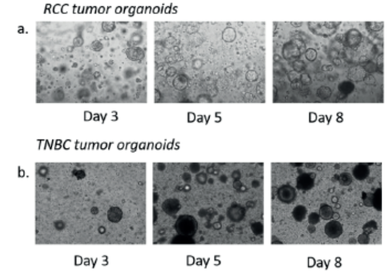
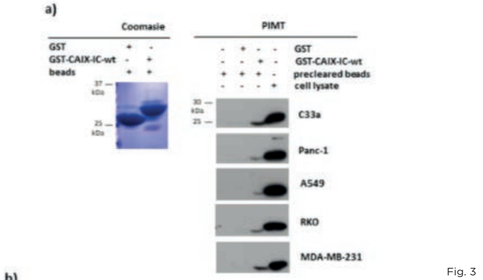


Fig. 4

Fig. 4 / Representative image of tumor organoids prepared from renal carcinoma (a) and from triple negative breast tumor (b) cultured in the presence of extracellular matrix on the 3rd, 5th and 8th day after processing of the patient's tumor tissue. The images were taken with Axiovert 40 CFL – Carl Zeiss microscope, objective magnification 10x.



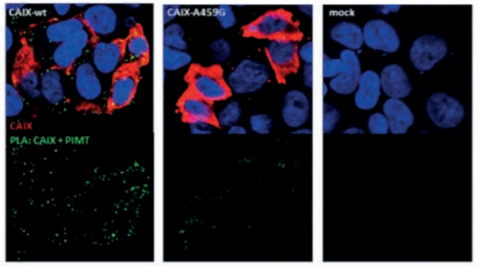


Fig. 3

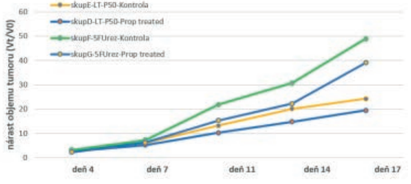


Fig. 2

Cell interactions in the tumour microenvironment and their pharmacological modulations

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Term of solution
7/2017 — 12/2021
Budget from agency
249 120 €
Project ID
APVV-16-0446

Research subject

In the last decade, several studies displayed the crucial role of tumour microenvironment (TME) and its components in carcinogenesis. Dynamic interactions of cancer cells with the microenvironment consisting of stromal cells (cellular part) and extracellular matrix (ECM) components (non-cellular part) are crucial for cancer progression and metastasis. Better understanding of the underlying mechanisms involved in the cross-talk between stromal and cancer cells in the TME may lead to the implementation of novel strategies targeting specific TME interactions resulting in improved anti-cancer therapy.

Aim of the research

The main goal of the research project was to characterize cellular interactions participating in the formation of TME and the possibility of their modulation by natural compounds and their newly synthesized derivatives.

Achieved results

The most important results:

a) We provide novel evidence that the activity of stromal fibroblasts (normal – HF and cancer associated – CAF) towards the four commercially available PDAC cell lines results in an efficient tumour-stroma cross-talk. Our *in vitro* experiments using conditioned media clearly showed certain specific differences in the growth, spread, clonogenic potential, and phenotype between the four tested PDAC cells lines. In these experiments, the most aggressive behavior was acquired by Panc-1 cells (increased number and size of colonies as well as remaining expression of vimentin and keratin 8), whereas PaTu-8902 cells were rather inhibited. Of note, the conditioned media had an inverse effect on the size and number of colonies in MIAPaCa-2 cells, whereas CAPAN-2 cells were rather stimulated (increased size and number of colonies). Markers associated with epithelial-to-mesenchymal transition (Slug, Snail and E to N cadherin switch) of cells were up-regulated in Panc-1 and MiaPaCa-2 cells whereas PaTu-8902 and CAPAN-2 cells were not deregulated (Fig. 1)..

b) In our experiments with lichens *Pseudevernia furfuracea* (L.) Zopf we found that lichen extract (PSE) and its metabolite physodic acid (Phy) inhibited TGF-β-induced epithelial-to-mesenchymal transition (EMT) in breast cells. We detected down-regulation of several EMT-associated proteins, such as N-cadherin, fibronectin, β-smoothe muscle actin, Slug and Smad2/3. Moreover, tested compounds were able to act at a very low concentrations (IC_{10}) preserving viability of tested cell lines. We also found similar effects in cancer associated fibroblasts. Furthermore, PSE and Phy altered the angiogenesis process, important for cancer growth and spreading (Fig. 2)

c) Finally, we proved that that β-escin exerts inhibitory effect on the basic fibroblast growth factor (bFGF)-induced angiogenesis *in vitro* and *in vivo* (Fig. 3). We suggested that these effects may partially be explained by suppression of Akt activation in response to bFGF and by inhibition of EFNB2 and FGF-1 gene expressions in endothelial cells.

The results of the project were published in 25 *in extenso* papers in international journals indexed in CC, WoS and SCOPUS and have been cited over 170 times.

Benefits for practise

- our results point to heterogeneous regulation of cancer cells by CAFs, which at the current state-of-art medicine preclude simple targeting and development of an effective treatment strategy and rather requires establishment of an individualized tumour-specific treatment protocol.
- natural substances have a good potential to modulate TME, which could contribute to the development of new approaches in anti-cancer therapy

Fig. 1 / Effect of condicioned medium from normal fibroblasts (HF) and cancer asssociated fibroblasts (P10 and P11) on the expression of proteins associated with EMT.

Fig. 2 / Effects of PSE and Phy on blood vessel formation in the ex ovo CAM assay. (A) Representative images of the most effective 72 h treatment with PSE, Phy in the presence or absence of VEGF (25 ng/ml). Quantitative analysis of angiogenesis by measuring vessel density (B), total vessel network length (C) and total branching points (D)

Fig. 3 / Effect of β-escin on bFGF-induced angiogenesis on fibrin gel bead assay (A, B) and microcapilary formation in CAM assay (C, D).

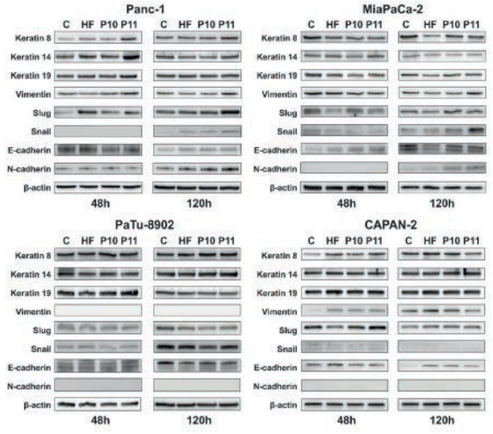

Fig. 1

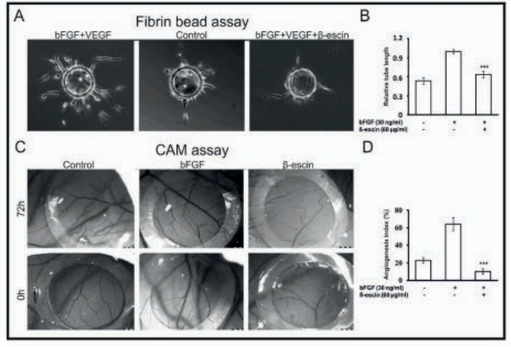

Fig. 3

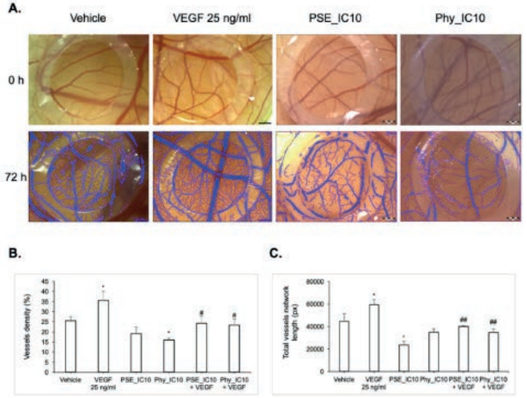

Fig. 2

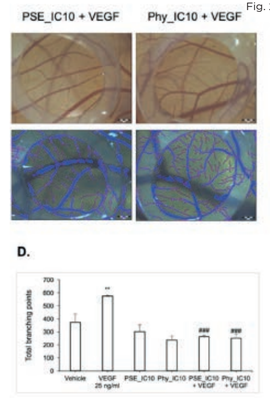

Fig. 2

AGRICULTURAL SCIENCE

Metagenomic approach for the identification and characterization of viral diseases in selected medicinal plant species

Principal investigator
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Applicant organisation
University of Žilina Institute of High Mountain Biology
Participating organisation
Biomedical Research Center - Institute of Virology, Bratislava
Term of solution
7/2017 — 6/2021
Budget from agency
249 161 €
Project ID
APVV-16-0026

Research subject

Plants from the families (*Papaveraceae*) and (*Solanaceae*) belong to cultivated crops, but they are also an integral part of the agro-ecological interface or wild plant communities, where they represent an important and so far little-explored reservoir of viral pathogens. In the project, we focused on the identification and characterization of viral pathogens widespread on these plants using a highly progressive next-generation sequencing (NGS) method.

Aim of the research

- development of a suitable next-generation sequencing (NGS) strategy directly in environmental samples of plants from families Papaveraceae and Solanaceae with the aim of enriching the proportion of viral sequences in the analyzed sample
- characterization of the complex "virome" in naturally infected plants
- complete or partial molecular characterization of the genome the most widespread viruses and research on the regional molecular diversity of viral populations present in Slovakia
- evaluation of the influence of evolutionary factors influencing the spread, diversification of plant viruses and the overall dynamics of the pathosystem
- development of molecular tools for specific and sensitive detection of important viruses, study of their epidemiology on natural host plant species in various agroecological conditions of Slovakia
- analysis of the effect of viral infection on the production of alkaloids in model plants at the expression level of genes encoding selected enzymes of the alkaloid metabolic pathway

Achieved results

Using massively parallel sequencing (NGS) to analyze *Papaveraceae* and *Solanaceae* target plants with varying degrees of virus infection expression, we highlighted the complexity of the plant 'virome' and the frequent occurrence of mixed plant infections. In poppy plants (*Papaver* sp.), we found the presence of turnip mosaic virus (*TuMV, genus Potyvirus*). Analyzes of NGS data from tomato, pepper and eggplant and *Datura stamonium* L. led to the identification of several viruses that had not been recorded in Slovakia before, e.g. *Tomato bushy stunt virus* (*Tobamovirus genus*), *Pepper mild mottle virus* (*PMMoV, Tobamovirus genus*), *Potato virus M* (*PVM, Carlavirus genus*), *Watermelon mosaic virus* (*WMV*), The original knowledge was the detection of persistent (cryptic) viruses in the pepper gene pool: *pepper cryptic virus -2 (PCV-2, genus Deltapartitivirus*) and *pepper endornavirus* (*BPEV, genus Alphaendornavirus*), which spread vertically. In the case of all viruses, we determined their complete genome sequences and evaluated the molecular diversity of local isolates. In the case of several viruses (e.g. *PVM*), we detected highly divergent isolates escaping routine conventional diagnostics. The obtained data therefore allowed us to develop or optimize sensitive and specific diagnostic molecular procedures. We have found that tobamoviruses use wild plant species of the *Solanaceae family* (*Datura stramonium L.*) as reservoirs for their existence and spread. During the artificial infection of *Datura stramonium L.* plants with tobamovirus, we recorded an increased expression of genes involved in the biosynthesis of tropane alkaloids. We can therefore consider tobamoviruses as potential elicitors of tropane alkaloid production. The achieved results were published in 9 scientific publications registered in the Web of Science database.

Benefits for practise

The results of the project are important above all for phytosanitary and cultivation practice. The information obtained is important from the point of view - effective diagnosis, prevention and subsequent eradication (removal) of affected individuals, especially in breeding stands. This will significantly prevent/slow down the spread of viral infection significantly reducing plant production. An important finding is the role of the plant population occurring in the agroecological interface (a significant part of which is made up of plants of the *Papaveraceae* and *Solanaceae families*) in the natural distribution cycle of viruses. Wild plants are an important and so far little-targeted deposit of viruses, subsequently attacking culturally and economically important crops. For biotechnological practice, the evidence of increased expression of genes involved in the biosynthesis of tropane alkaloids during the infection of dahlia plants with tobamoviruses is an important fact. This fact has a huge potential in terms of industrial production of tropane alkaloids.

Fig. 1 / (*Lettuce big-vein associated virus)* on tomat plants

Fig. 2 / Experimental inoculation of poppy plants by *Turnip mosaic virus* - healthy plant on the left, infected on the right

Fig. 3 / Presence of *Cucumber mosaic virus* on cucumber plant

Fig. 4 / The use of an antibody to monitor the accumulation of the cpasid protein of *Tomato mosaic virus* by immunological methods (ELISA and western blot) in edible tomato plants

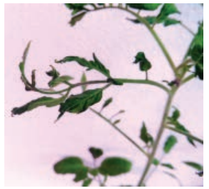

Fig. 1

Fig. 2

Fig. 3

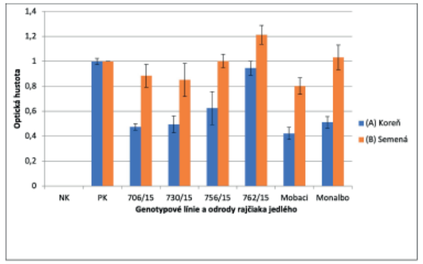

Fig. 4

Fig. 5

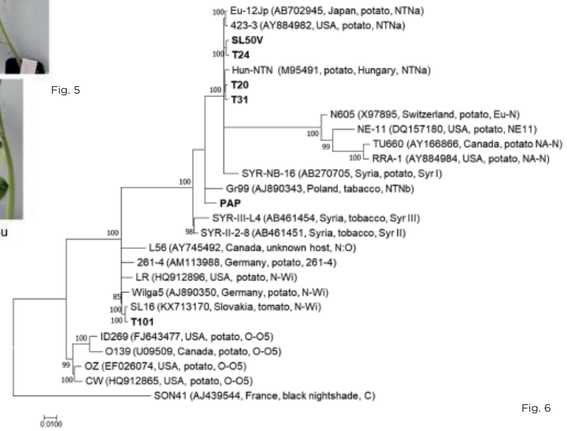

Fig. 6

Fig. 5 / Symptoms of Tomato mosaic virus infection on different tomato varieties

Fig. 6 / Phylogenetic relationships between isolates of *Potato virus* Y

Transcriptome and proteome in prediction of animal model vitality

Principal investigator
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Applicant organisation
National Agricultural and Food Centre
- Research Institute for Animal Production Nitra
Term of solution
7/2017 — 12/2021
Budget from agency
248 360 €
Project ID
APVV-16-0067

Research subject

One of the most discussed problem is its susceptibility to different types of diseases associated with reduced of vitality. This aspect has also negative effect on growth rate, thus significantly increasing the overall cost of the holding, significantly adversely affects the economy holdings and can affect the results of experiments using animal models. For this reason, is one of the present major challenges in the animal breeding to find candidate genes and the application of selection for prediction of vitality, selection on higher vitality and resistance of animals to diseases. Candidate gene testing is an approach used to define DNA markers. Transcriptome and proteome analyses have been introduced as a research tool in most fields of biomedical research. They permit the identification of prognostically relevant biomarkers, gene expression profiles, and the understanding of complex molecular mechanisms in cell physiology and pathology. The project is given the complexity of looking the issue of applying new selection approaches to predict animal vitality, while maintaining optimal utility parameters. Using molecular-genetic and immunological methods, we analysed the expression of selected genes, focusing on their influence and use possibilities in the selection and prediction of the vitality of animal models - rabbits. We evaluated selected indicators of the usefulness of defined groups of rabbits and the expression of selected genes of innate and adaptive immunity.

Aim of the research

The aim of this project was evaluated vitality (mortality) and selected indicators of performance defined groups (haplotypes, genotypes) of rabbits and evaluation of expression selected genes innate and adaptive immunity using modern molecular genetics (RT² PCR) and immunological assay (ELISA) methods. Another aim of this project was to find and design the candidate genes for prediction vitality of animal model – rabbit.

Achieved results

In defined populations of rabbits, we performed a complete evaluation of selected production and reproductive indicators and evaluated mortality during the fattening period.
Based on the results of the evaluation of performance parameters, vitality and expression of innate immunity genes evaluated in PGR genotypes of rabbits, we proposed as a potential candidate gene (CD1D, CD28) in relation to better vitality and more efficient production and reproductive properties. From the evaluated adaptive immunity genes as potential candidate genes, we recommend: CD80, CCR4, CCR8, IL15, IL17A and STAT6. The obtained expression results and other monitored indicators show that the genes CCR4, CCR8 and especially IL17A are in a negative correlation with better reproductive, production indicators as well as the vitality of growing rabbits. In contrast, in the case of IL15 and STAT6 gene expression, a positive correlation was found with the observed reproductive and production parameters. In relation to the second evaluated rabbit group with cyt-b polymorphism (Ha-1 and Ha-2), we proposed potential candidate genes: CD80, CCR4, CCR8 and IL17A.
We performed registration of oligonucleotides (OC cytb F; OC cytb R) to identify haplotypes-molecular polymorphisms in cytochrome b mtDNA in the gene bank BOLD System. http://www.boldsystems.org/index.php/Public_Primer_PrimerSearch (keyword: 16-0067)

Benefits for practise

Innovative dimension of the project obtained in original and complex results of the expression of selected genes and their relationship to the vitality of rabbits during the rearing period and in relation to selected production indicators. The benefits of the project are based on the possibility of direct application in the selection program and breeding practice. The utilization of the results is determined by increased demands for support and sustainability of animal production, more efficient animal production, production of healthy animals and functional foods of animal origin. The involvement of the proposed candidate genes in the selection process of animals will contribute to economic benefits expressed mainly by streamlining animal production, reducing the total mortality and morbidity of animals, especially during the fattening period. We designed a detection plate for the RT²PCR system (custom array) with the innate and acquired immunity genes of rabbits, with the potential for direct use in the business sphere focused on specialized breeding farms and in industries using rabbits as a model animal.

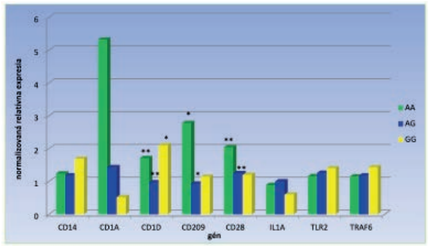
Fig. 1 / Amplification curves of RT² PCR showing cycle threshold (Ct) values of selected immunity genes

Fig. 2 / Melting curve analysis of selected immunity gene transcripts detected by real-time RT² PCR: cDNA samples are amplified in real-time PCR with specific set of primers and melting curve analysis is performed to confirm the identity of the PCR products.

Fig. 3 / Normalized gene expression for innate immunity of different PGR genotypes

Fig. 4 / Normalized gene expression for adaptive immunity of different PGR genotypes

Fig. 5 / PCR-RFLP Electrophoresis results for rabbit PGR gene.
The polymorphism and three different genotypes (AA, AG and GG) in PGR gene promoter were detected by used PCR RFLP method.
M = Marker 1 kbp DNA Ladder
PGR genotypes: (AA 558bp; GG 416+142 bp; AG 558+416+142 bp)



*p≤0.05; ** p≤0.01

Fig. 3

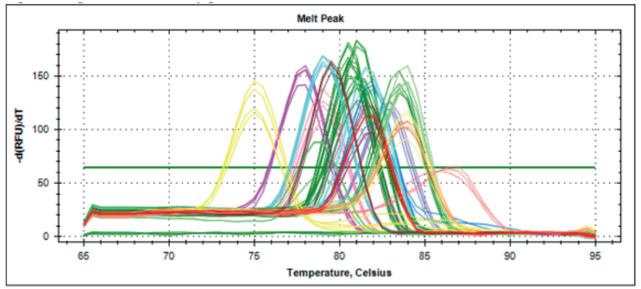
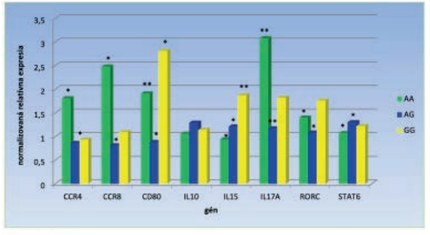


Fig. 2



*p≤0.05; ** p≤0.01

Fig. 4

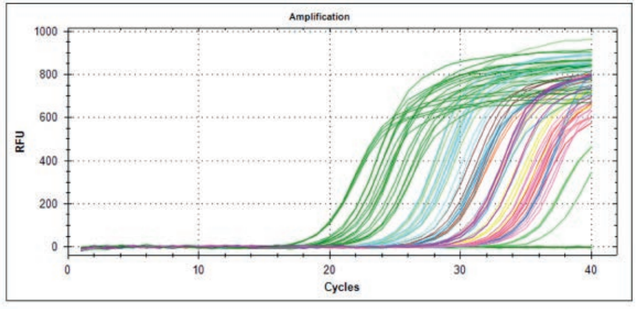


Fig. 1

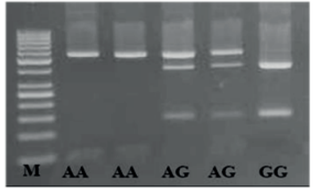


Fig. 5

Complex utilization of plant biomass in biofoods with added value

Principal investigator
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Faculty of Chemical and Food Technology, Faculty of Mechanical Engineering in Bratislava
Participating organisations
Institute of Forest Ecology in Zvolen,
University of St. Cyril and Methodius in Trnava
- Faculty of Natural Sciences,
National Agricultural and Food Center
- Food Research Institute in Bratislava
Term of solution
7/2017 — 12/2021
Budget from agency
249 925 €
Project ID
APVV-16-0088

Research subject

The subject of the research was the identification, isolation and possibilities of using biologically active substances in plant biomass, especially in the bark and in the hitherto unused parts of sea buckthorn. The research was aimed to fulfill current trends and EU requirements aimed at foods that are innovative, ecological and contain natural substances obtained from sustainable plant biomass. Furthermore, their use in food was investigated, which replaced synthetic raw materials, created organic foods and "novel food" enriched with natural substances with added value.

Aim of the research

The aim of the project was: i) to find suitable methods of treatment of plant biomass providing the highest possible yield of biologically active substances; ii) to isolate and investigate these biologically active substances; iii) screening tests to determine the antioxidant and antimicrobial effectiveness of isolated mixtures of substances and their fractions; iv) *in silico* and *in vitro* to investigate the biological activity of selected substances isolated from plant biomass, effective in the prevention of civilization diseases; v) apply parts of plants as well as isolated mixtures of substances in organic foods and "novel food" with added value; vi) study the use of plant biomass in dermal preparations and obtaining green chemicals.

Achieved results

The most significant result was the isolation and *in silico* and in vitro analysis of biologically active substances from the waste bark of the common spruce (*Picea abies*). The most significant of them is probably abietic acid (Fig. 1), which we applied in our further research. We found that the antibacterial effect of abietic acid is multiplied due to the synergistic effect with beta-sitosterol. Antibacterial and antifungal effects were recorded when they acted together on the tested microorganisms. These substances are found to a significant extent in the waste tree bark produced during their processing. Thus, a still significant source of biologically active substances, but also various green chemicals, is offered.

From the point of view of international cooperation, we obtained the most interesting results in the cooperation focused on the research of sea buckthorn. The exceptional value of sea buckthorn (Fig. 2) can be seen in the presence of lipophilic antioxidants (mainly carotenoids and tocopherols) and hydrophilic antioxidants (flavonoids, tannins, phenolic acids, ascorbic acid) in remarkably high amounts. The result of this collaboration was a joint work published in the renowned journal Food Research International with an impact factor of 6.475, category Q1 Food Science & Technology. The publication is aimed at summarizing and critically comparing scientific information regarding the composition of micro and macro nutrients and bioactive substances of sea buckthorn and the possibility of their use in human nutrition.

Another ground-breaking work was focused on predicting the storage of vegetable oils in real storage conditions. We have published our own kinetic model for predicting the stability of vegetable oils, which is applicable in real storage conditions. Graphical management of the results from the kinetic model enables easy reading of the stability of vegetable oils stored in PET packaging under different conditions (Fig. 3). The work was published in the renowned journal Food Packaging and Shelf Life with an impact factor of 6.429, category Q1 Food Science & Technology.

Benefits for practise

The results of the project found practical application in practice, but also resonated in the scientific community. They have been cited in many important journals in the WOS database, thereby advancing the research teams' previous knowledge. Co-researchers from the National Agricultural and Food Center, Research Institute in Bratislava devoted themselves to applications of by-products of sea buckthorn processing, especially seeds and pressings, into puffed breads at the company Celpo, s.r.o., Očová. Other new products enriched with sea buckthorn plant biomass were presented at the exhibitions Danubius Gastro 2018 and Agro complex 2018. The results of the research were converted into successful cooperation, adjustment of the recipe, or the setting of new production techniques for the processing of plant biomass in the enterprises Calendula a.s., Tvrdošovce P.D., McCarter a.s., StuVital s.r.o., and Tate & Lyle Boleráz, s.r.o. These companies participated in the research during the solution of the project, provided sources of plant biomass, some standards and equipment necessary for the solution of the project.

Fig. 1 / Abietic acid and its probable mechanism of antibacterial action.

Fig. 2 / Sea buckthorn as a source of biologically active substances useful for human nutrition.

Fig. 3 / Induction period (IP in days) predicted for vegetable oils stored in a temperature range of 25-90 °C and a surface-to-volume ratio between 10 and 300 1/m with an oxygen pressure fixed at 0.21 bar (atmospheric pressure).

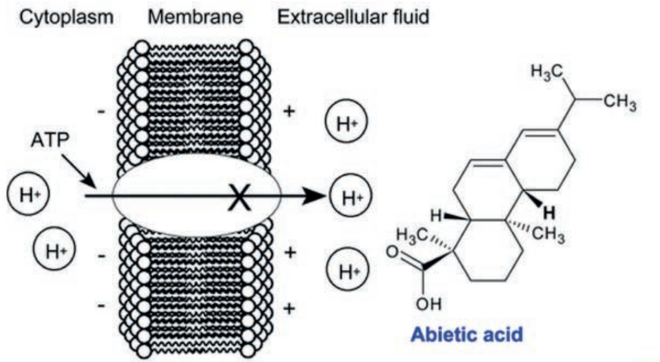


Fig. 1

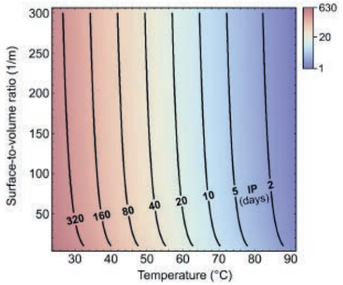


Fig. 2

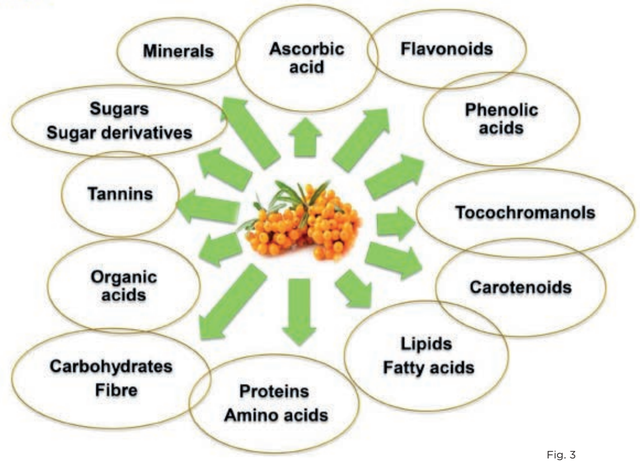


Fig. 3

Research on the impact of process innovation on lifespan of forestry machinery tools and components

Principal investigator
doc. Ing. Richard Hnilica, PhD.
Applicant organisation
Technical University in Zvolen
Participating organisation
Slovak Academy of Sciences, Institute of Materials Research
Term of solution
7/2017 — 12/2020
Budget from agency
249 044 €
Project ID
APVV-16-0194

Research subject

The subject of the research was to assess risk point on work tools and components of forestry machines. A comprehensive analysis of the current status in using of working tools and components from material and technology points of view. In order to find stress-strain state of tools and components it was performed FEM analysis. Further, it was performed state material analysis of specimens to examine their physical and mechanical properties, microstructure characteristic and resistance to abrasive wear.

Aim of the research

The goal of the project is based on of system and complex approach to problem solving of tool wear and components of forestry machines under real working conditions to design new materials and innovative production sequence of tools and components to enhance their lifetime. Apply them to samples of blanks and after successful testing and selecting the most appropriate methods for increased durability applied to the currently used components to be experimentally tested in operation. Delivering these goals will be set out the application recommendations for a transfer of knowledge to users components of forestry machines.

Achieved results

Based on complex analyses, abrasive tests, we have developed technical solutions in order to increase the technological life of technical elements of selected machines used in forestry.
Specific solutions concern working tools (so-called teeth) for crushing undesirable growths. By evaluating the analyses of mechanical properties, microstructure, mixing quality and cohesiveness of individual layers of materials, as well as the total quality of hard weld deposit metals, we assume that the best results will be achieved with working tools with hard weld deposit made of HR HAG tubular wire, 53 N electrode and E 520 RB welding electrode. When hard surfacing of hard weld deposit metal to selected places on the work tool, it is important to pre-adjust the tool by grooving on the most exposed surfaces and then apply the hard deposit metal by hard surfacing. The solution mentioned is protected by utility model no. 9285.
We provide a technical solution for extending the technological service life of work tools for road milling machines by applying weld deposit metals with the E DUR 600 and ABRADUR 58 electrodes to the functional surfaces of the work tool.
Based on laboratory analyses of selected methods of snow ploughshares renovation, we arrived at two technical solutions extending the technological life, namely a snow ploughshare solution with a hard weld deposit layer OK 84.58 and a snow ploughshare solution whose base material is welded with HARDOX 450 material on places most exposed to wear.
For rollers, we arrived at technical solution to extend their technological life by applying a hard weld deposit metal to the profile of the roller with a weld deposit electrode ESAB 83.50, which is most suitable for use due to the quality of welds, high hardness and good properties in the melting zone.
The technical solution for extending the technological life of the branching knife consists in attaching the cutting tool to a solid shaped jaw in the lower part. This variant reduces the operating costs of the machine, because it is not necessary to replace the entire branched jaw, but only the cutting edge. The solution mentioned is protected by utility model no. 8555.

Benefits for practise

The request to solve the problem of significant and frequent wear of working tools and components came directly from practice, and the results achieved from the experiments performed are fully applicable in forestry operations. These are mainly the working tools of forest milling planer (crushing undesirable growth, mulcher, soil tiller, road milling), working tools of harvesters and processors (branching knives) and components such as pulleys used in forest harvesting (cable systems, directional pulleys) and snow plows intended for clearing forest roads. The possibility of increasing the technological lifetime of these technical elements is therefore very much in demand. We see the benefit in the increase the lifetime of tools, minimalize downtime forest machines in order to exchange of wearing tools and components, as reflected by reducing fuel consumption forest machines as well as an overall increase in efficiency work of forest machines which will contribute to increasing the competitiveness of forestry companies.

Fig. 1 / 3D scan of the working tool show the loss of material

Fig. 2 / SEM of the surface of the worn tool - plastic deformation on the front surface of the tool: a), b), c), e), f) uneven plastic deformation of the surface layers; d) microstructure of the tool outside the plastically deformed surface.

Fig. 3 / The most exposed surfaces of the working tool with the subsequent application of hard deposit metal by welding

Fig. 4 / Branching knife with replaceable cutting edge.

Fig. 5 / Visualization of the technical solution of snow ploughshare modifications: a) unmodified ploughshare; b) modified ploughshare - change of ZM to HARDOX 450; c) modified ploughshare - hard weld deposit metal OK 84.58 on ZM; d) modified ploughshare - ZM welding with HARDOX 450.

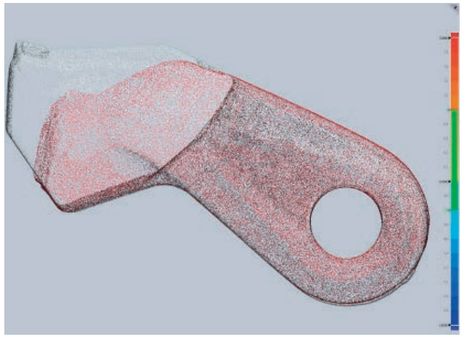


Fig. 1

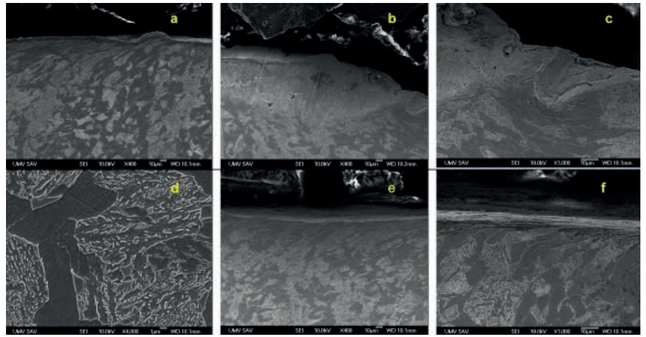
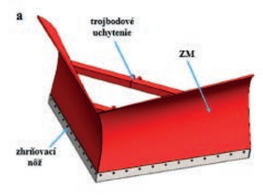
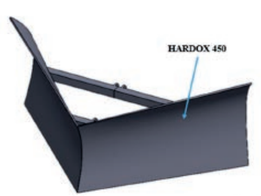


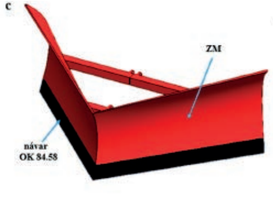
Fig. 2

Fig. 3

Fig. 4







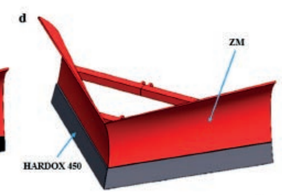


Fig. 5

Fig. 5

Aspects of cytoprotectivity and cytotoxicity of bioactive compounds in various conditions

Principal investigator
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Applicant organisation
Slovak University of Agriculture in Nitra
Term of solution
7/2017 — 12/2021
Budget from agency
249 998 €
Project ID
APVV-16-0289

Research subject

Risk, bioactive, bioprotective substances can be important in the prevention of various diseases induced by exogenous and endogenous factors. The experiments were used to clarify the effect of selected substances on the functional indicators of the organism under experimental load. To analyse the influence of new and undescribed natural substances on the antioxidant status, structural and functional properties of sex cells, cell cycle regulation, the genital system served as a sensitive barometer with an impact on the quality of reproduction and overall health. For determination of bioactive substances effects and the subsequent possible application in the physiology of animals, it was necessary to determine the protective or toxic effect, as well as their mutual interactions due to the elimination of health risks. The existence and progress of animal physiology, reproductive biology, and toxicology require the systematization and comparison of physiological processes at the animal and human levels.

Aim of the research

The main aim of the project was the determination the effects of selected xenobiotics, bioactive and bioprotective substances on animal tissues, reproductive potential of animals, study of ecotoxicological interactions and effects of toxic substances on parameters of animal health in natural and model conditions.

Achieved results

Based on the approved stages, several research tasks were carried out, resulting in a total of 154 publications, of which 34 were published in impacted journals and 4 were monographs. The main goal of the experimental analyses of the first and second stages of the project was the preparation and extraction of natural products (plants, macroscopic fungi, and essential oils), the determination of the exact composition of natural extracts, when individual fractions and antimicrobially effective fractions are created using chromatographic methods. In the next stage of the project, we dealt with the influence of bioactive substances and xenobiotics on the reproductive potential of animals, where the positive effect of taurine on the quality of the ejaculate of rabbits, pigs and stallions was clearly confirmed; taurine and caffeine on the quality of turkey ejaculate; Lippia citriodora and verbascoside on rabbit ejaculate quality, resorcinol on bull ejaculate quality and Viscum album on stallion and rabbit ejaculate quality. The negative impact of environmental pollutants on the reproductive potential (ejaculate quality and RedOx markers) of fish, stallions, bulls, boars, and turkeys in natural conditions was confirmed. The next stage can be summarized as the study of ecotoxicological interactions, the effects of xenobiotics as well as bioactive substances on animal health in vivo. As part of the experiments, the health status (biochemical and haematological parameters) and oxidative stress of various animal species (rat, rabbit, sheep, fish, pheasant, horse) were evaluated in association with bioactive substances and toxicants. As part of the experiments, potentially toxic doses of xenobiotics and bioactive substances were determined in the monitored animal species. The last stage of the project was focused on determining the effect of selected toxicants and bioactive substances using animal cell models in in vitro conditions. It is primarily about monitoring the secretory and functional activity of the cells of the male reproductive system, the degeneration of the seminiferous epithelium, disorders in the development and function of sperm, or the occurrence of oxidative stress. The targeted identification and description of specific internal or external molecules participating in the cellular response to internal and external stimuli is of fundamental importance for the protection or preservation of human and animal health.

Benefits for practise

The individual outputs of the project within the reproductive part provide extensive information on the effects of natural biologically active substances, endocrine disruptors, and xenobiotics on the male reproductive system (ejaculate quality, sperm oxidative stress, mitochondrial activity, membrane integrity, viability, and steroidogenesis of Leydig cells). The main investigative methods focused on biochemical, haematological, and RedOx markers give us clear information about the limit amounts of pollutants and bioactive substances. The main goal of the experiments focused on animals in the natural environment was to monitor the impact of pollutants as a complex of active substances, since substances do not act individually in such an environment. The project was aimed to study the effects of environmental toxicants, but at the same time it describes the potential effects of bioactive substances on physiological processes or intracellular metabolism with the possibility of maximum elimination of negative impacts as well as the application of protection of human and animal health.

Fig. 1 / Graphical abstract of study "JAMBOR, Tomas, et al. Parallel effect of 4-octylphenol and cyclic adenosine monophosphate (cAMP) alters steroidogenesis, cell viability and ROS production in mice Leydig cells. Chemosphere, 2018, 199: 747-754." published as part of the project APVV-16-0289. Our study reveals that increasing concentration (0.04-5.0 mg/mL) of 4- octylphenol (4-OP) were able to decrease the steroidogenic capacity of the exposed cells. Source: https://doi.org/10.1016/j.chemosphere.2018.02.013

Fig. 2 / Heat-map with clustering results (r - Pearson's correlation coefficient). Effect of trace metals content on all parameters measured in semen samples of Cyprinus carpio. Trace elements, such as Mn, Fe, Se, Sr, and Zn showed positive association with spermatozoa qualitative parameters (VCL, VSL, DAP, DCL, DSL, and BCF). Typical toxic element, Hg, negatively affected progressive motility and interacted with production of malondialdehyde, what we can consider as direct effect to lipid peroxidation. Source: https://doi.org/10.1016/j.jtemb.2018.08.005

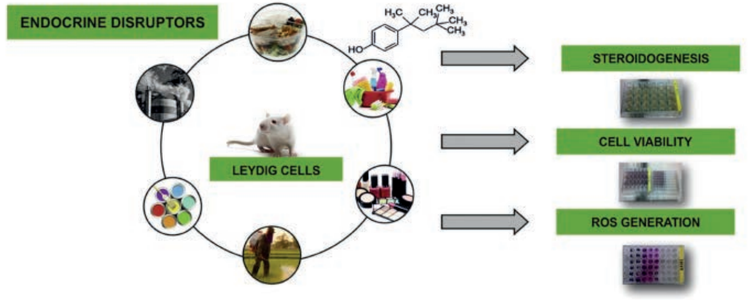

Fig. 1

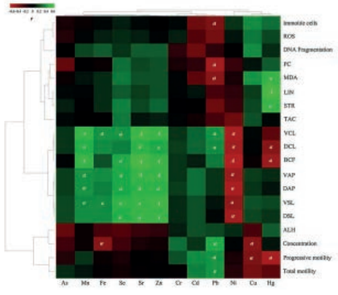

Fig. 2

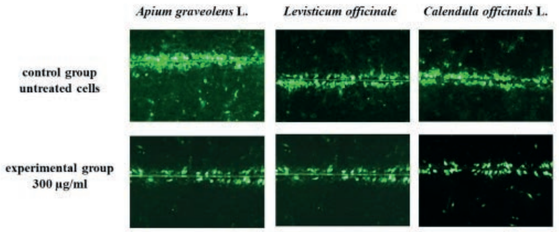

Fig. 4

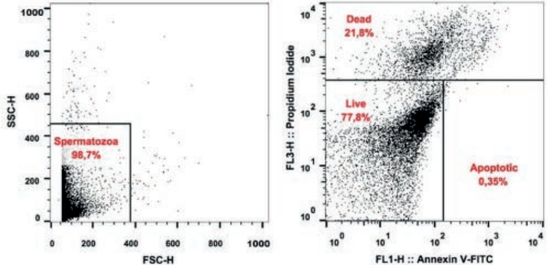

Fig. 3

Fig. 3 / Illustrative dot plots used for the flow-cytometric evaluation of the stallion spermatozoa apoptosis. Cells found in the lower left quadrant (AnV−/PI−) were identified as live; cells located within the lower right quadrant (AnV+/PI−) were determined as apoptotic; upper quadrants (AnV−/PI+ and AnV+/PI+) included dead sperm cells. Source: https://doi.org/10.3390/life11111238

Fig. 4 / The effects of herbal extracts on intercellular communication (GJIC) in TM3 Leydig cells after 24 h exposure in vitro. Quantification of GJIC activity was performed by SL/DT method with lucifer yellow fluorescent staining. Source: https://doi.org/10.33549/physiolres.934675

Extreme effects of climate change and their impact on forest growth and production (FORCLIMEX)

Principal investigator
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Applicant organisation
National Forest Centre (NFC)
Participating organisation
Technical University in Zvolen
Term of solution
7/2017 — 6/2021
Budget from agency
249 972 €
Project ID
APVV-16-0325

Research subject

Increasing frequency and intensity of extreme meteorological events affects adversely the environment, and generates significant ecological and economical losses to the forestry. The subject of the research was to evaluate the impact of extreme climate effects on the forest component of the natural environment and to use the unique potential of long-term forestry databases, a network of research plots and technical infrastructure, which the research organizations (National Forestry Center and Technical University in Zvolen) have at their disposal.

Aim of the research

The main objective of the project was to develop the web-application on biometeorological monitoring that would be sustainable in the long-run. The application should to provide operative assessments of an array of climate related risks to forests (drought, fires, changes in pest population dynamics, etc.) to support the forestry practice, state administration, broader public and education. Besides, using extensive forestry and climatological databases, the negative impacts of recent meteorological extremes (especially drought and heat) on the growth and production of forest stands were analytically evaluated.

Achieved results

- In accordance with the main goal, within the project was created an integrated web-application of forest meteorological monitoring ForestWaeather (www.forestweather.sk), which should serve as a support tool for operational assessment of natural risks related to extreme signals of the ongoing climate change (heat waves, drought, insects, fires). This open and dynamic system of continual collection of meteorological data contributes to better understanding of interactions between the changing near-ground atmospheric layer and a forest ecosystem.
- The analysis of long-term data from forest monitoring providing the information on the growth of main tree species revealed the decreasing trend of the relative basal area increment of beech, spruce, and pedunculate oak over the last two decades, while the reduction was apparent mainly in the years with heat waves and drought (2003, 2006).
- Eco-physiological research performed in the years 2012–2019 in the experimental forest stand Bienska dolina showed that common beech is a tree species sensitive to drought. The lack of available soil water was reflected in radial stem changes, in a substantial limitation of the transpiration process and also in the change in the correlation strength between the sap flow and environmental factors. Persistent soil drought caused cumulative shrinkage (contraction) of beech stems over a longer period, thus limiting or reducing growth, which was particularly pronounced in the years with extreme climate of 2012, 2015 and 2018. Using machine learning techniques for modelling of the impact of meteorological factors, drought indicators (MDS - max. daily stem contraction and ΔW - water deficit) on sap flow, we identified potential evapotranspiration, global radiation and vapour pressure deficit as the most important predictors.
- Process-based modelling of carbon, water and nutrients cycling (using the biogeochemical model Biome-BGC MuSo) in selected ICP Forests Level-II plots showed to be a reliable tool to analyse the impact of changing environmental conditions on the growth and development of ecosystems. The positive signal for the future progress of forest monitoring is that its databases meet the requirements of process-based ecosystem models, which brings new opportunities to link the ecological research and practical forestry planning.

Benefits for practise

As part of the project, two contracts were concluded on the use of the project results in forestry practice, namely with the entities State Forests of the Tatra National Park and Forests of the Slovak Republic, state enterprise. Based on these contracts, the subjects were provided with the following results: access to the integrated network of forestry meteorological monitoring stations; operational information from the online application of forestry biometeorological monitoring focused on the assessment of risks in forest ecosystems resulting from climate change (drought, fires, etc.) and a list of outputs in the form of scientific publications focused on the issue addressed. Indirectly affected users of the solution outputs and the target group of data users are also the users of the forest area on which the forestry meteorological stations are based, as well as the managers of the forest stands where long-term research or experimental measurements of various parameters take place.

Fig. 1 / Logo of the web application of forest meteorological monitoring in Slovakia – ForestWeather

Fig. 2 / Map of the stations of forest meteorological monitoring (Forest Weather) in forest areas of Slovakia with displaying of current air temperature values

Fig. 3 / Measurement of sap flow and stem circumference changes by automatic dendrometers in an experimental forest beech stand at the Bienska dolina location (450 m above sea level)

Fig. 4 / Development of carbon stocks in individual layers of the forest ecosystem and precipitation-evaporation processes on the example of 2 research plots (Poľana – 850 m asl and Bienska dolina – 450 m asl). The simulations were carried out from the time of establishment of the stands to the present in a real climate and under changed environmental conditions using the ecosystem biogeochemical model Biome-BGC MuSo.

Fig. 1

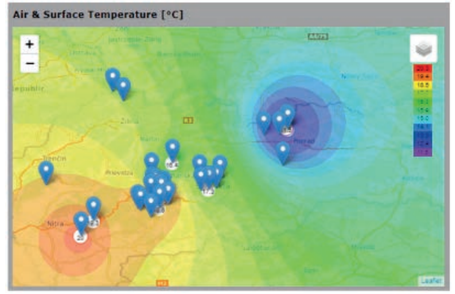

Fig. 2

Fig. 3

Fig. 3

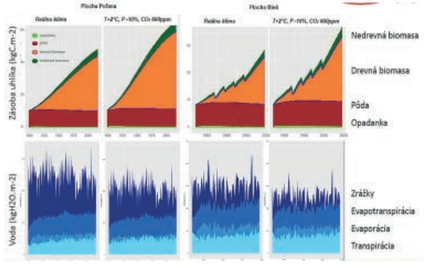

Fig. 4

Use of animal models for tauopathies for identification of molecular pathways involved in the etiology of neurofibrillary degeneration

Principal investigator
Mgr. Kováčech Branislav, PhD.
Applicant organisation
Neuroimmunology SAS
Term of solution
7/2017 — 10/2020
Budget from agency
245 914 €
Project ID
APVV-16-0531

Research subject

Neurofibrillary degeneration, which is characteristic of the formation of pathological aggregates of tau protein, is the major hallmark of several neurodegenerative diseases including the most prevalent Alzheimer's disease (AD). Abnormal forms of tau protein occur under diseased conditions and are no longer capable to fulfill their physiological function but self-aggregate to form filaments of various types, which gradually grow into neurofibrillary tangles. These diseases which are characteristic for tau pathology are still incurable. Since protein-protein interactions are elementary for many processes, it is proposed that their dysfunction or deregulation is located upstream, leading to various pathological conditions. Interaction partners of tau protein and involved molecular pathways can either initiate and drive the tau pathology or can have neuroprotective roles, by reducing pathological tau changes or inflammation. The subject of the research was to map the tau-interacting proteins and their associated molecular pathways which may be implicated in tau pathology. For this purpose, we used the unique transgenic rat models expressing the pathological forms of tau proteins which induce neurofibrillary degeneration in the brains of these animals.

Aim of the research

The aims of this project were: (1) Identification of normal and pathological interactome of tau protein in transgenic rat models and selection of candidates for further validation; (2) Validation of selected identified tau interactors by co-immunoprecipitation and *in vitro* biophysical methods, using animal and cell models for tauopathies and human brain tissues; (3) Bioinformatic analysis of molecular pathways participating in tau pathology and identification of their key players which may influence tau pathological processes.

Achieved results

Using an *in vivo* crosslinking approach in rat models for AD and immunoprecipitation of tau-positive protein complexes followed by MALDI-ToF mass spectrometry analysis, we identified 328 proteins presumably interacting with tau. Using bioinformatical analysis and ranking of identified proteins we obtained 175 high confidence tau-interacting proteins (Fig. 2.). Among these high confidence interactions, 71 were novel, 92 were previously detected in rat, mouse, and/or human, and an additional 12 were only predicted in human. In addition, from 175 high confidence proteins, 39 were annotated to Alzheimer's, 10 to Parkinson's, and 22 to both diseases. Furthermore, detected tau partners were analyzed for associations with pathways using the pathDIP tool. We have identified 2192 molecular pathways from 22 different databases with which our proteins are associated. The most significant pathways were related to programmed cell death, insulin-mediated glucose transport, and cell cycle regulation. We further ranked the identified 175 high-confidence tau-interacting proteins by preferential occurrence in either transgenic or control animals and we selected 8 candidate interactors for further validation. The validation was performed using two methods: (1) co-immunoprecipitation of proteins extracted from rat brain stems and human cerebral cortex with tau pathology and healthy controls using tau as bait; (2) fluorescent colocalization with tau in SH-SY5Y neuroblastoma cells expressing tau proteins. Through coimmunoprecipitation and colocalization, we confirmed 5 of 8 investigated candidates to interact with tau – BAIAP2, GPR37L1, NPTX1, PSMD2 and RAN. These proteins fulfill important functions in brain cells as is regulation of axonal growth, synapse formation and neuronal differentiation (BAIAP2, GPR37L1 a NPTX1), proteasomal degradation (PSMD2) and nucleocytoplasmic transport (RAN).

Benefits for practise

Our results contributed to discovery of novel proteins which can either initiate and drive the tau pathology or can have neuroprotective roles in neurodegenerative diseases with tau pathology. Identified molecular pathways can contribute to the understanding of the pathogenesis of tau protein and could facilitate the selection of biomarkers which are necessary for early and reliable diagnostics of the disease. Further characterization of individual interactions with tau and their consequences to neuronal processes will enable design of molecules for inhibition or stabilization of the interactions. This may eventually lead to the development of effective drugs against AD and other tauopathies.

Fig. 1 / Schematic representation of physiological tau protein functions in neurons. (A) The axonal tau stabilizes microtubules (MTs), and it can also bind actin filaments thus facilitating cytoskeleton networking. Furthermore, tau regulates MT dynamics by interacting with end-binding (EB) proteins. Tau also competitively inhibits the interaction of dynein and kinesin to MTs and thus influences intraneuronal transport. (B) In the synapses, tau protein can be directly translated, and during neuronal activity, it is released into the synaptic cleft. Tau is a known interacting partner of the BAR domain-containing proteins such as BAIAP2, PACSIN1, and BIN1, that ensure the curvature and shaping of the neuronal membrane. Tau may play a role in the removal of developmental NMDARs and their replacement for mature NMDARs in dendrites. The developmental/mature NMDARs exchange is important for the formation of new synaptic connections. (C) In the nucleus, tau interacts with DNA and RNA, maintains their integrity, and protects them from oxidative damage.

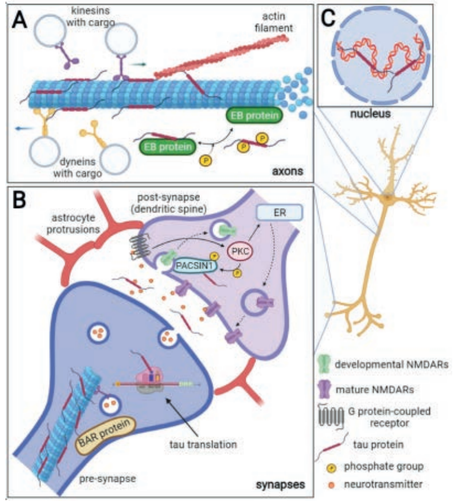

Fig. 1

Fig. 2 / Interaction map of 175 proteins identified by mass spectrometry. Proteins identified preferentially in control (ctrl) or transgenic (TG) animals are visualized separately and highlighted with red (identified only in TG), orange (preferentially in TG), green (only in ctrl), and turquoise (preferentially in ctrl). Proteins with relation to Alzheimer's disease (blue edges), Parkinson's disease (pink edges), or both diseases (gold-yellow edges) are shown separately in network. Node colors represent Gene Ontology Molecular Function (legend).

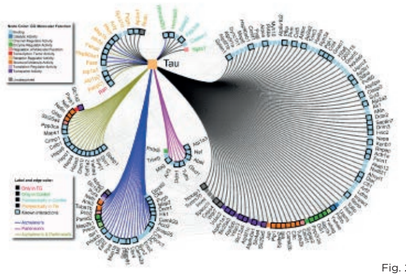

Fig. 2

Fig. 3 / Positive tau colocalization with its selected proteins in SH-SY5Y neuroblastoma cells. Cells were fluorescently stained with anti-tau (green) and anti-investigated candidate (red) antibodies. Colocalization of tau with its partner is seen in yellow (selected regions highlighted by yellow arrows) as a result of green and red emission signal overlay.

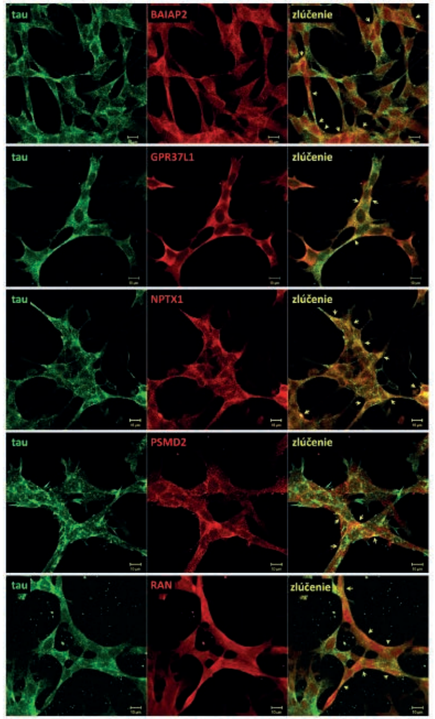

Fig. 3

SOCIAL SCIENCE

Food Security, Poverty, and Vulnerable Groups: the Role of Policies

Principal investigator
prof. Ing. Ján Pokrivčák, PhD., M.S.
Applicant organisation
Slovak University of Agriculture in Nitra - Faculty of Economics and Management - Department of Economic Policy, Nitra
Participating organisation
National Agricultural and Food Centre - Research Institute of Agricultural and Food Economics, Bratislava
Term of solution
7/2017 — 12/2020
Budget from agency
198 083 €
Project ID
APVV-16-0321

Research subject

Food security has long been a huge challenge for mankind. Covid-19, climate change and the war in Ukraine have made this problem even more striking. Around 12% of the world's population suffer from food and nutrition insufficiency, and 3 billion people in the world do not have access to healthy food. Inadequate food security does not exist only in developing countries. A large number of people in Slovakia and other EU countries cannot afford nutritious food, which has a negative impact on their health. These are mainly low-income and vulnerable groups.

Aim of the research

The project was focused on the analysis of food security in transition countries of Central and Eastern Europe. We estimated price and income elasticities of demand, which indicate that for many population groups the access to healthy food is considerably limited by income. Food diversity in Central and Eastern European countries is insufficient and this has a significant impact on the health status of the population.

Achieved results

Our results show that food diversity is positively influenced by a higher income. Especially in the case of low-income households, increase in income or a decline in real food prices is positively correlated not only with improved food security, but also with their health status. In all transition countries, there is a positive relationship between people's education and the quality of consumed food. Policies generating income for vulnerable groups or supporting education play an important role in improving well-being and health. Compared to the majority, Roma population consumes less diversified and unhealthier diet. The differences between Roma and non-Roma population are partly explained by differences in income, education or household structure, but about wo thirds of the differences in demand for food diversity between Roma and non-Roma segments of the population are a consequence of discrimination against Roma.

Our results show that after reaching a certain level of income, people pay more attention to food diversity. Overweight and obesity are also a function of income. Low-income groups suffer from overweight the most, which is reflected in their poorer state of health. Because of economic constraints low-income and vulnerable groups cannot afford diversified and healthy diets.
We confirmed that the reduction of VAT rate on selected foods from 20% to 10% in Slovakia in 2016 was an effective change. If the government had simultaneously increased the VAT rate on non-food products, such a reform could have been fiscally neutral, improving household welfare and reducing income/expenditure inequalities.

Benefits for practise

The analysis based on concepts and models developed in this project helped to detect problems in achieving food security, to identify groups of population who are vulnerable to food insecurity or the consequences of income and price shocks, and to determine factors reducing or limiting food security. The findings are useful for policy makers when designing policies and individual measures to eliminate difficulties in achieving food security and to ensure its stability in transition countries, but they can be generalised to the whole European population too.
In addition, the evidence of differences in the quality of diet of Roma compared to other population groups enables us to focus on their mitigation, to increase food security of these households, thus contributing to the improvement of their health, decreased costs for treatment of diseases, increased socioeconomic performance of the households, which in turn leads to better inclusion of this ethnic group and to lower discrimination. To reduce poverty and promote social inclusion, it is necessary to use to a greater extent tools supporting the adaptability of workers and enterprises, supporting the access to employment and creating jobs in agriculture, fighting against discrimination and facilitating the access of marginalised and vulnerable groups to the labour market.

Results of the project are published in high-ranked international journals such as Food Policy, Food Security, Economics and Human Biology, Oxford Economic Papers and others and they were presented at world and European scientific congresses.

Fig. 1 / Share of expenditure on food and soft drinks (% of total expenditure, 2016)
Fig. 2 / Composition of the diet of Slovak households (% share of expenditures on food components in total expenditures on food)
Fig. 3 / Development of food consumption and household diet diversity in Romania

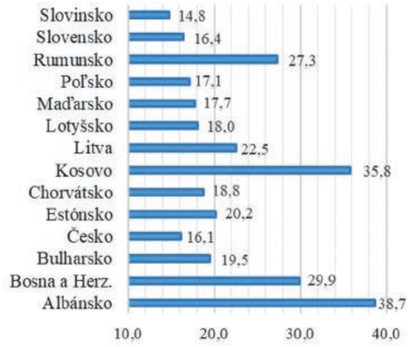

Fig. 1

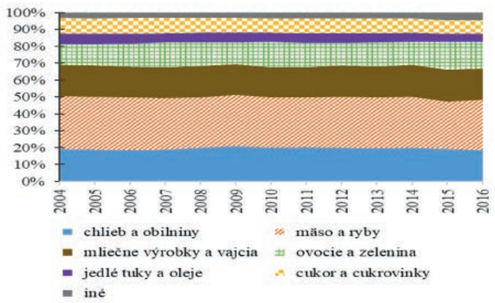

Fig. 2

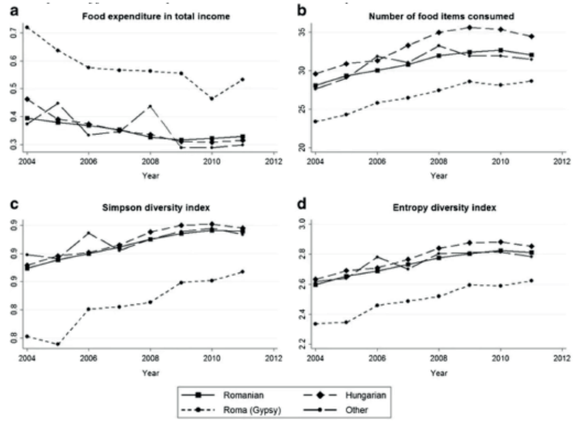

Fig. 3

Current Images of the Socialism

Principal investigator
PhDr. Monika Vrzgulová, CSc.
Applicant organisation
Institute of Ethnology and Social Anthropology SAS
Term of solution
7/2017 — 12/2021
Budget from agency
176 952 €
Project ID
APVV-16-0345

Research subject

The project represented basic qualitative research carried out using the oral history method. It aimed to record the memories of daily life during the communist regime in Slovakia (socialism) with the spotlight on the period 1960-1989. Interviews capture eye-witnesses' memories of their family life, work, and free time.

Aim of the research

1. the first digital oral history archive of recordings of interviews about life under socialism, their transcripts and accompanying materials (bio-questionnaires, interview summaries and keywords, informed consent of the interviewee).
2. identification of current mental and public representations of socialism in the individual memories of the actors of this period and their intergenerational transmission within the family (tracing intergenerational communication in contemporary families).
3. Open access to the results: preparing a web page of the project - for professionals and the public. Preparation of an educational DVD (a compilation of critically selected parts of the interviews) for schools. Presentations at conferences.

Achieved results

The project´s main aim was to create a digital Oral history archive at the Institute of Ethnology and Social Anthropology, SAS. Although the COVID-19 pandemic, which persists, has radically affected our plans since the spring of 2020, we have managed to record 95 audio and video interviews. They are a new part of the Scientific Collections of the IESA SAS as the first scientific digital archive of oral history interviews on socialism in Slovakia. The project website www.obrazysocializmu.net presents a space for sharing knowledge with different audiences. The results of our activities, as well as teaching tools for primary and secondary school teachers, based on the results of the research, are available for academics, teachers, and the public as well. A relevant tool for sharing the information with the expert audience are two monographs, 14 papers in peer-reviewed international and national journals, and two edited volumes of academic journals. Members of the project team organized two international conferences and one international panel Current Images of Socialism at the 2019 SIEF Congress titled Track Changes: Reflecting on a Transforming World. The international conference Memory of the Communist Past (2020, online) met with interest. It was a successful dissemination output of the project. During three days, 38 presentations in 12 panels, represented current research of prominent scientific institutions from Slovakia, the Czech Republic, the Netherlands, Germany, Poland, Austria, Romania, the Russian Federation, Slovenia, Italy, and Ukraine. Members of the project team discussed the outcomes at scientific forums in Slovakia and abroad. Furthermore, they shared their knowledge in formal and non-formal education (up to 600 pupils and students), and with the general public. Educational materials based on the research interviews are available on the project's website. The project goals were fulfilled and even expanded. Members of the team published two scientific peer-reviewed monographs (2020,2021), prepared educational materials (2020, 2021), and organized a competition for High school students called *Photographies with a story*. Participation in the international project COST Action Slow Memory (2021-2025) is the follow-up of the project.

The project's results were applied to the teaching aids for primary and secondary school teachers; in subjects history, social studies, and ethical education. We prepared 3 sample lessons based on the transcripts of our research interviews (2020) and two audiovisual teaching aids: sample lessons based on video recordings of research interviews (2021).

Reflection of the curricular reform in a pedagogical work of basic school teachers

Principal investigator
prof. PaedDr. Štefan Porubský, PhD.
Applicant organisation
Matej Bel University in Banska Bystrica Faculty of Education
Term of solution
7/2017 — 6/2021
Budget from agency
163 000 €
Project ID
APVV-16-0458

Research subject

Pedagogical work of primary school teachers in the teaching process with regard to the level of implementation of the declared goals of the 2008 curriculum reform.

Aim of the research

To identify factors determining the processes of implementation of curriculum reform in primary schools. To analyse and identify the degree of application of defined reform indicators in the real teaching practice of teachers in primary schools and to create a typology of teachers in relation to their attitudes towards curriculum reform and its implementation in the educational process.

Achieved results

The team of researchers has long been dedicated to researching the issue of curriculum changes and reforms at both the macro level, the mezo level (implemented within the project APVV–0713–12 Implementation of Curriculum Reform in Primary Schools in the Slovak Republic) and the micro level (within the currently completed project). This creates prerequisites for systematic and systematic scientific and research work in the field of studying school and curricular reforms. In addition, in the current project, it was possible to identify the degree of application of defined reform indicators (according to the State Education Program) in the real teaching practice of teachers as an indicator of the success of the implementation of the curriculum reform in the teaching process in primary schools. Based on research findings, it has been shown that primary school teachers often work with problem tasks in the teaching process and use them as a means of activating students in the process of teaching and learning. The indicator "The teacher encouraged students to think" was the highest rated indicator among all monitored indicators. On the other hand, it turned out that the teachers are generally weak innovators of the teaching process and are not ready to fulfil the expectations declared in the state curriculum documents, because they only exceptionally used an inquiry or an experiment in the teaching process. Likewise, they only use formative student assessment methods to a very small extent, and the use of cross-subject relationships is a rare rather than a common phenomenon. For the teachers involved in the research, how to develop moral values in pupils also seems to be a big problem. In relation to teachers' expectations towards a well-set curriculum reform, it was possible to define 5 descriptions of a successful curriculum reform using the Q methodology with an overview of the characteristics of the participants, which were associated with the given factors: A – responding to global challenges, B – respecting the diverse educational needs of children, C - consensual, explanatory, based on thorough knowledge of the problems of school practice, D – pragmatic, thoughtful and sustainable, E – principled and responsible. Our findings show that the ideas of education actors in Slovakia are formed against the background of both global and local discourse. Successful as well as unsuccessful attempts at systemic change determine the direction of people's thinking about what should be the goal of the reform, as well as how it should be implemented.

Benefits for practise

The findings from the research carried out in the project currently have a significant degree of application in the field of curricular policy of the Slovak Republic, namely in the field of preparation of the curricular reform of basic education. Through the active participation of the members of the APVV implementation team in the preparation of the curricular reform, the research findings of the APVV project are also based on the conception of the starting materials, but especially when designing the implementation strategies of the reform. This is especially true for the findings related to teachers' opinions and attitudes towards the 2008 curriculum reform. In this context, our research findings also served as a basis for the preparation of the monitoring report of the World Bank working group, which participates in the preparation of the current curriculum reform in Slovakia as an advisory authority. The results of research findings also determine the concept of teacher education at PF UMB, especially in the preschool and elementary pedagogy program.

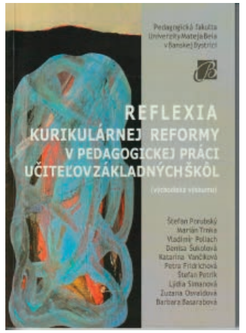

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 1,2,3 / A selection from publications published by a collective of researchers

Fig. 4 / The scientific conference EDUCATION FOR THE FUTURE was held in 2019 at Matej Bel University - Faculty of Education in Banská Bystrica, where members of the research team spoke in a panel discussion What kind of teachers do we have and what kind of teachers do we want to have and presented partial results of their research in the section intended for doctoral students in the field pedagogy.

Fig. 5,6 / Speech of members of the research team at the first meeting of The Central commission for pre-primary and basic education of the State Pedagogical Institute preparing the reform of the basic education curriculum in Banská Bystrica in 2021.

Fig. 5

Fig. 6

Forecasting of Regional Development and Assessment of Effectiveness of Regional Policies Using the Structural HERMIN Model

Principal investigator
Ing. Marek Radvanský, PhD.
Applicant organisation
The Institute of Economic Research SAS
Term of solution
7/2017 — 12/2020
Budget from agency
216 913 €
Project ID
APVV-16-0630

Research subject

Slovakia ranks among the European countries with the highest level of regional disparities, and their mitigation has been one of the priorities of all Slovak governments since its establishment. Nevertheless, economic policy in the Slovak Republic tends to underestimate the specific impact of measures at regional level. Relatively little attention is also paid to analytical support for decision-making and development of forecasts at regional level. The main objective of the research carried out in the project was the development and application of quantitative tools for decision support, analysis and forecasting of the impact of possible regional and cohesion policy (RP and CP) measures, towards increasing the effectiveness of those policies instruments while respecting the objectives of sustainable and inclusive growth.

Aim of the research

The project consisted of three interconnected parts. The first was the methodological part, which analysed the development of the RP and CP up to the present period, their objectives, and identified the economic policy instruments for achieving them. The core element of the simultaneous application part of the project was the modification of an extended HERMIN-type structural econometric model together with the creation of a system of 8 satellite models for each NUTS 3 region. These submodels were enriched by inter-sectoral linkages through a (regional) input-output approach. The HERMIN model, approved at national level by the European Commission for the assessment of the CP effects, as well as for the forecasting, has not been applied in this form before. Selected approach thus represents a significant methodological shift internationally. The final section was devoted to the evaluation of existing policies, as well as to the synthesis and use of the results of forecasts and simulations for the needs of economic policy support.

Achieved results

First stages of the project were aimed at describing the current situation in addressing the issue of measuring regional disparities, methods used to evaluate regional and cohesion policy. These were summarized in the 2019 monograph "Modelling regional development in the Slovak Republic and evaluation of the effectiveness of regional policies". The project made progress in the estimation of inter-regional flows of goods, services and labour, based on the methodology contained in the paper "An alternative approach to the construction of multi-regional input-output tables of the Czech Republic : application of the CHARM method", published in the foreign peer-reviewed journal EMPIRICA. In the field of regional disparities assessment, the researchers have brought an alternative metric for their measurement and the results of the analysis based on this new indicator have been published in the paper "Nominal and discretionary household income convergence : The effect of a crisis in a small open economy" in the journal Structural Change and Economic Dynamics. In the field of ex-ante analyses of the impact of cohesion policy in the programming period 2021-2027 on regional disparities within the Central European countries (Slovakia, the Czech Republic and Poland), the study 'Does Cohesion Policy help to combat intra-country regional disparities? A perspective on Central European countries", which was published in the prestigious peer-reviewed journal Regional Studies.

Benefits for practise

In the field of practical application of the HERMIN model cooperation with the Polish team and members of the Commission for Spatial Economics and Regional Planning of the Polish Academy of Sciences has been accomplished in 2020. This cooperation represented follow-up on the bilateral APVV SK-PL-2015-0058 project. During project implementation research team initiated collaboration with the Czech Government Office within which in collaboration with colleagues from Ministry of Finance, the developed HERMIN based approach was adapted to Czech conditions and used in the preparation of the regional ex-ante evaluation of the proposed new EU Framework Programme 2021-27. In Slovakia, the information from the updated HERMIN model was used in the cooperation of the principal investigator as a member of the expert commission for the planning of the Programme period 2021-27 at the Ministry of Regional Development and Investment.
New methodological approach based on the Integrated Econometric Input-Output Model developed within project activities was implemented in the conditions of Malta in cooperation with the Jobsplus (Public Employment Service agency) and the Ministry of Labour and Education (international cooperation induced by the implementation of the APVV project). The possibilities of using the application outputs in real conditions were illustrated in the final monograph of the project entitled "Regional Policy and the Labour Market after 2020".

Fig. 1 / Cover of the monograph Modelling Regional Development in the Slovak Republic and Evaluation of the Effectiveness of Regional Policies

Fig. 2 / Cover of the monograph Regional policy and the labour market after 2020

Fig. 3 / Cumulative cohesion policy multipliers in CZ, SK and PL regions 2021-2027.

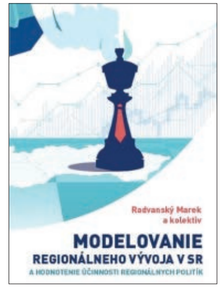

Fig. 1

Fig. 2

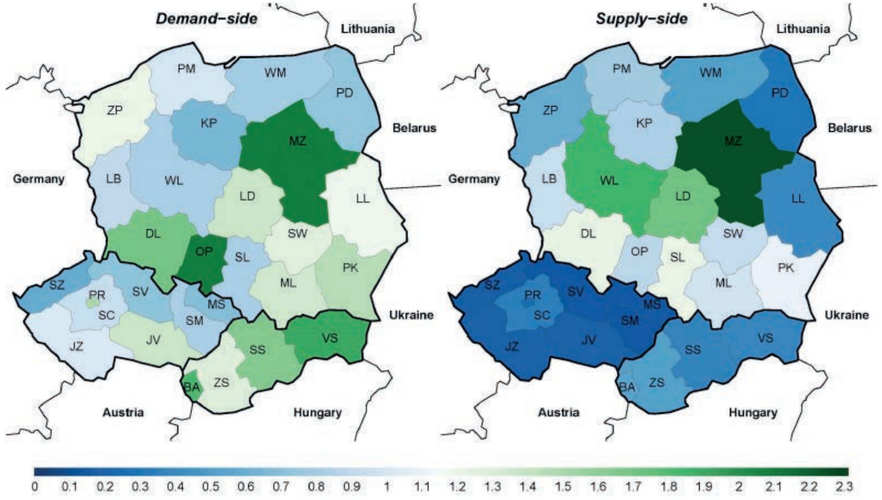

Fig. 3

HUMANITIES
SCIENCE

“From Denarius to Euro.” The Money Phenomenon in the History of Slovakia from the Middle Ages till the Present Day Period

Principal investigator
PhDr. Ludovít Hallon, DrSc.
Applicant organisation
The Institute of History of the SAS
Term of solution
7/2017 — 12/2021
Budget from agency
207 531 €
Project ID
APVV-16-0047

Research subject

The presented project focuses on new or little-studied issues related to the role of money in the history of Slovakia. The project provides a long-term view, from the Middle Ages to the present day and is based on new research into sources and new methods used in the global historiography of economic and social history. The project built on the existing knowledge from previous research into the history of money, finance and financial processes that particularly dealt with the development of currency, means of payment, finance and central banking. Although the investigators based the project on the existing knowledge, they mainly focused on less-studied or new topics such as the fiscal and budget policy of the state, fiscal management of regional authorities, self-governing regions, cities, districts and municipalities as well as the fiscal management of the individual types of economic operators based on the structure and character of the period.

Aim of the research

In regards to some topics, research into the history of money and financial processes in Slovakia has progressed quite far, however many topics have only been partially studied or almost completely overlooked. Therefore, the major topic of the presented project is extremely topical and can make a substantial contribution to the research and synthetic processing of the development of the phenomenon of money in Slovakia. The project aimed to research new or little-studied issues related to the role of money in Slovakia from a long-term perspective, from the Middle Ages to the present day. The project also attempted to observe the individual, as a part of the history of the role of money and financial processes. From a methodology viewpoint, the project attempted to introduce methodological concepts and processes used in global historiography that are new or less well-known in Slovak historiography (business history, new economic history), based on an assessment of their suitability for the study of the economic history of Slovakia.

Achieved results

Over the course of 4 years, the investigators published 7 scientific monographs (2 of them internationally), 2 collective monographs, 2 studies with the character of a scientific monograph and 6 studies in magazines that are registered and processed by the ISI Current Contents. The high output level of the research group can clearly be seen from the 86 scientific and professional studies that were completed. The number of public lectures and presentations made by members of the team in various media outlets must be viewed in a highly positive light, despite restrictions related to the Covid-19 pandemic, they were able to make as many as 74 of them. The contributions of the various project investigators dealt with the history of money and financial processes, for example, the economic situation in medieval mining cities, economic aspects of the Kingdom of Hungary in the early modern period and the construction of aristocratic residences considering their management by aristocrats, managers and businessmen and social care in the Kingdom of Hungary. Attention was also paid to proto-capitalist businessmen, the modern business elites, the management and office workers in socialist enterprises, the reforms of the 1960s (Šik) and the issue of the Czechoslovak gold reserves from 1938–1982 along with some other minor topics. The project goals, that were set at the beginning, were fully met.

Benefits for practise

Apart from the high number of scientific and professional studies and scientific monographs, the investigators also attempted to ensure that the lay public was well informed of the results of the project during its lifetime. Educational institutions and libraries organised lectures open to the general public. They often included public discussions of the results of scientific research. Popularising lectures were intended for the general public and focused on various topics of economic history, from the Middle Ages to the 20th century. The documentary *“Fantastic Middle Ages”*, *Mining* and *Metal Extraction in the Middle Ages* explained the connection between the funding of the military campaigns of Louis the Great and the import of the painting style of religious frescoes to Gemer. The topic of the early modern times was publicised through presentations and articles about the residences of the rural nobility in Szepes County and the very topical issue of epidemics and their economic impact on the country. More recent historical subjects dealt with the wartime economy and rationing, economic losses after World War II, the economic situation in Slovakia after the end of World War II and the paradoxes that came from a centrally planned economy in Czechoslovakia. The results of the research were presented to the public through public lectures and media presentations, there was a total of 74 of them over the lifetime of the project. The topic of this APVV project is of high importance and can be used within history lessons at various types of schools. It is appropriate additional study material that deals with the role of money and finance and the development of the Slovak economy.

Fig. 1 / Scientific publications produced by the project and published at a foreign publishing house

Fig. 2 / Scientific publications produced by the project and published in a Slovak publishing house

Fig. 3 / The final collective monograph published as part of the project.

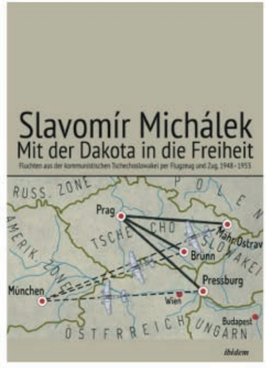

Fig. 1

Fig. 2

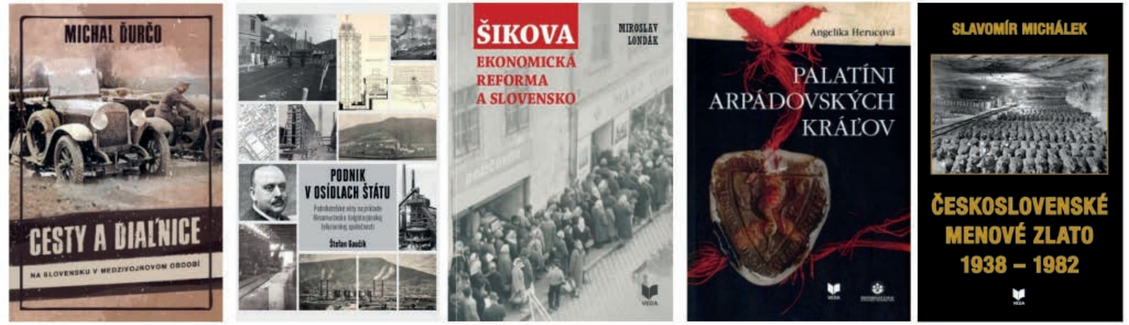

Fig. 3

Comprehensive Memory Portal and Historical Atlas of Slovak Cities (Bratislava and Košice)

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Applicant organisation
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Participating organisation
Faculty of Arts, Pavol Jozef Šafárik University in Košice
Term of solution
7/2017 — 12/2021
Budget from agency
163 246 €
Project ID
APVV-16-0383

Research subject

Ca. from the 60s of the 20th century there was an inspiration from geography in Western historiography (the so-called "spatial turn"). Historical city atlases (HTAs) became the main output of the new trend. So far, 20 European countries have been involved in the work on the HTA (more than 570 parts so far). Slovakia did not reflect this trend for a long time. The main investigator therefore prepared an applied research project, which intended to create a synthesis of data on the topographical and urban development of two selected Slovak localities in the past (up to approx. 1900 with a focus on the period from the 12th/13th C.) with the aim of preparing a new data presentation model.

Aim of the research

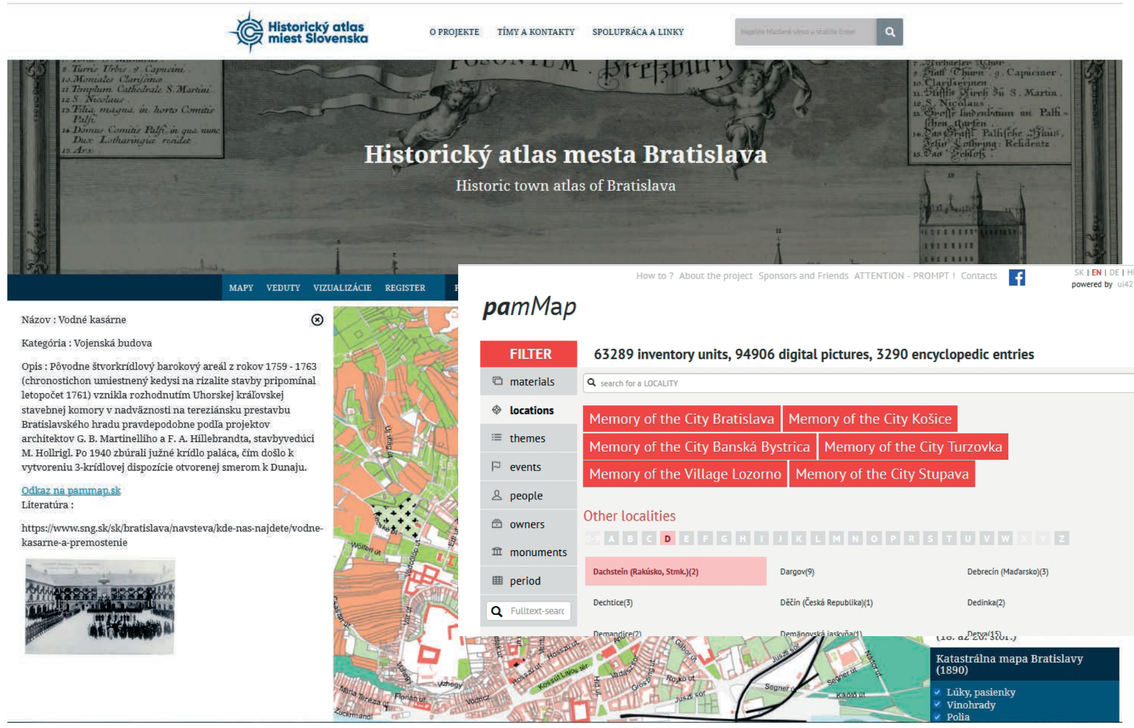
As part of the applied research, a modern platform for displaying the urban and topographical development of cities was to be created ("atlas application"), as well as a portal that would synthesize the possibilities of an encyclopaedia, a database, and partly also an HTA ("memory portal"). In addition to the two main outputs, the Bratislava and Košice teams were to publish outputs from research at home and abroad.

Achieved results

Two main applied results emerged - a locally specific portal with historical town atlases (https://towns.sk/) and a universal memory portal for the history of (Slovak) towns and villages (https://www.pammap.sk/) with a focus on Bratislava, Košice and Banská Bystrica.
Unlike older European print atlases, the portal with historical atlases of Slovak cities (HAMS) enables fast and modern online access to research results (they can also be updated and/or corrected). It offers three basic functionalities: map views of the development of the given city, historical visualizations of the city, gazetteer (encyclopaedic overview of the development). The e-atlas allows to interactively select a number of development maps, compare historical, reconstruction and modern plans ("overlapping them" with the use of opacity) and especially - on the reference cadastral map (before 1895) it provides information up to the level of an individual public building (building development and a link to its display on PamMap, where there are or will be its owners and inhabitants).
HAMS is linked to the second basic output – the PamMap memory portal. It was originally created only for Bratislava, but thanks to the support of the APVV, it was able to expand with digitized data to more than 400 other locations. It enables sophisticated filtering by combining up to 8 filters (e.g. place, time, people, material, topic, type of monument, etc.). Unlike other memory portals, it combines digitized historical sources not only from official memory institutions (archives, museums etc.) but also from families and private collections (they make up over a third of the fund).
In addition to the two main applied outputs, dozens of team members created 5 monographic texts and 33 studies on the solved problem published in Slovakia, the Czech Republic, Hungary, Austria, Germany, Switzerland, Romania and Italy. While before the creation of the project, Slovakia was a "hole on the map" in the field of HTA, after the finalization of the project, it offers a more modern path than most projects in other European countries.

Benefits for practise

The most significant contribution is the memory portal for the history of (Slovak) towns and villages (https://www.pammap.sk/). He "opened doors" to some memory institutions (archive depots and museum depositories can be viewed online). He made more than 63,000 historical sources available - of which approx. a third is in private collections and estates (i.e. they were completely inaccessible until now). It is the result of the so-called *iconic turn* not only in historiography but also in the whole society (the importance of image sources increased). Due to the combination of search filters, it made the search in collections and funds more efficient even for the employees of the cooperating memory institutions. Some institutions were not digitized at all and the project helped them. The portal had over 21,000 individual users only in the last year of funding (2021).
The portal with historical atlases of cities in Slovakia (https://towns.sk/) opens a geographical perspective on the development of the (so far) two largest cities in Slovakia. It offers geo-information for monumental preservation, urban planning, developers, publishers and editors, but also for the nostalgically curious public.
The publications were oriented towards basic research rather than applied research, but at least three monographs on the historical topography of Bratislava and Košice can be highlighted, which will help regional historians, conservationists, restorers, and those interested in the development of buildings and public spaces in this towns. Due to the modern methodology, the project can serve as a model for processing the development of other cities - not only in Slovakia.



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