Natural resources green technology & sustainable development

5

3rd-5th December 2024
ZAGREB CROATIA

BOOK OF ABSTRACTS

GREEN

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Dear colleagues and friends,

Welcome to the 5th edition of the esteemed International Scientific and Expert Conference, "Natural Resources, Green Technology, and Sustainable Development/5-GREEN2024." This highly anticipated event will take place in the vibrant city of Zagreb from December 3rd to 5th, 2024, marking a tradition that began in 2014 with the 1st GREEN conference. Driven by the success of our previous GREEN conferences, the primary objectives of this conference remains devoted to bringing together the world leading experts in the fields of natural resources, green technology, and sustainable development. Together, we aim to present recent advancements, exchange cutting-edge insights, and collectively tackle the pertinent challenges within these vital areas of research.

We feel very proud to organize this Conference with the support of International organizations IUFRO, EFI and EBTNA.

The conference is dedicated to challenges and opportunities in natural resource management, emphasizing potential of ecosystem management, sustainable production of food, implementation of green technology, biomass and bio-based industry, forest genetics and environment and climate change. Researchers from eminent institutions will present their recent achievements. The multidisciplinary approach will bring together scientists and experts together to discuss and highlight the latest achievements in science, illustrate new policies, demonstrate innovative techniques and outline sustainability of natural resources.

We use this opportunity to express gratitude to our patrons and Auspices, International Scientific and Organizing Committee as well as to all of you for your scientific involvement which will certainly contribute to the success of the Conference. Special thanks is addressed to sponsors who enabled the preparation of this event.

Thank you for joining us!

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CHAIR OF SCIENTIFIC COMMITTEE
Tamara Jakovljević

Table of Contents

CONFERENCE HALL MARKET

Hotel International

8.00-9.00 **Registration**
9.00-9.30 **OPENING CEREMONY**

CHAIRS: T. Jakovljević, I. Radojčić Redovniković

9.30.-09.45 **Robert Mavsar:** Robert Mavsar: Rethinking economic growth: how forests can lead us to a sustainable future, EFI - European Forest Institute

9.45–10.00 **Elena Paoletti:** IUFRO - The International Union of Forest Research Organizations

10.00-10.30 **COFFEE BREAK**

10.00-10.30 **Poster presentations (SESSIONS A&B)**

Lectures & Parallel sessions

CONFERENCE HALL MARKET1

Hotel International

SESSION A: **ENVIRONMENT AND CLIMATE CHANGE**

CHAIRS: A. De Marco, N. Potočić

10.30-11.00 **Alessandra De Marco:** Air pollution and climate change impacts on forests, ENEA, Italy

11.00-11.15 **Justin Sentian:** Assessing future isoprene emissions in Southeast Asia: climate change implications, Faculty of Science and Natural Resource, University Malaysia Sabah, Malaysia

11.15-11.30 **Giuseppe Quaratiello:** Exploiting hyperspectral data to predict photosynthesis and hydric status related-parameters and discriminate ozone (O3) effects on grapevine (Vitis vinifera L.), Department of Agriculture, Food and Environment, University of Pisa, Italy

11.30-11.45 **Claudia Pisuttu:** Ozone application as a useful tool against crop diseases in pre- and post-harvest, Department of Agriculture, Food and Environment, University of Pisa, Italy

11.45-12.00 **Ivan Limić:** Ion fluxes in precipitation, throughfall, forest floor solution and topsoil solution in Aleppo pine forest, Institute for Adriatic Crops and Karst Reclamation, Croatia

12.00-12.15 **Nataša Ravbar:** Advancing groundwater recharge monitoring in karst aquifers: a holistic approach, ZRC SAZU, Karst Research Institute, Slovenia; UNESCO Chair on Karst Education, University of Nova Gorica, Slovenia

12.15-12.30 **STRESSES - journal presentation by Jelena Romcevic, Journal Relations Specialist**

CONFERENCE HALL MARKET2

Hotel International

SESSION B: **SUSTAINABLE PRODUCTION OF FOOD**

CHAIRS: P. Lozano, M. Brnčić

10.30-11.00 **Roland Ludwig:** Enzymes contributing to sustainable food production, University of Natural Resources and Life Sciences, Austria

11.00-11.20 **Andreja Leboš Pavunc:** Use of by-products in the production of new generation encapsulated probiotics, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

11.20-11.35 **Marko Vinceković:** Encapsulation of Bifidobacterium animalis subsp. Lactis into composite biopolymer microparticles, University of Zagreb Faculty of Agriculture, Croatia

11.35-11.50 **Naiara Fernández:** Microformulation as a tool to enhance the performance of ascorbic acid as a food preservative, iBET, Institute of Experimental Biology and Technology, Portugal

11.50-12.05 **Filip Boratyński:** Microbial synthesis of commercially important flavor and fragrance compounds, Department of Food Chemistry and Biocatalysis, Wrocław University of Environmental and Life Sciences, Poland

12.05-12.20 **Filipa Burul:** The olive moth (Prays oleae bern.) attraction to volatile compounds of olive canopy, Institute for Adriatic Crops and Karst Reclamation, Croatia

12.20-12.40 **Antonela Ninčević Grassino:** Nutritional profile of pumpkin pulp after ultrasonic pre-treatment and vacuum drying, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

12.45-14.00 **LUNCH**

CONFERENCE HALL MARKET1

Hotel International

SESSION A: ENVIRONMENT AND CLIMATE CHANGES - *continues*

CHAIRS: J. Medak, L. Butorac

14.15-14.30 **Ivan Dugan:** Erosion control: tillage choices for sustainable agriculture, University of Zagreb Faculty of Agriculture, Croatia

14.30-14.45 **Jasnica Medak:** Biodiversity assessment using the biodiversity indicator and reporting system (birs) methodology at Holcim quarries in Croatia, Croatian Forest Research Institute, Croatia

14.45-15.00 **Anton Brenko:** Identification of living conditions of summer truffle (Tuber aestivum) in natural productive sites of Istrian peninsula, Croatian Forest Research Institute, Croatia

15.00-15.15 **Ivana Zegnal:** Inoculating various forest seedlings with black truffles, Croatian Forest Research Institute, Croatia

15.15-15.30 **Mirzeta Memišević Hodžić:** Phenotypic variation in leaf and fruit traits in natural Populations of Quercus petraea ((matt.) Liebl.) in Bosnia and Herzegovina, University of Sarajevo, Faculty of Forestry, Bosnia and Herzegovina

15.30-15.45 **Antonio Vidaković:** New insights into genetic diversity of European wild pear (Pyrus pyraster (L.) Burgsd.) And almond-leaved pear (P. Spinosa Forssk.) In Croatia. implications for their conservation and protection, University of Zagreb Faculty of Forestry and Wood Technology, Croatia

CONFERENCE HALL MARKET2

Hotel International

SESSION C: GREEN TECHNOLOGIES

CHAIRS: R. Ludwig, T. Rezić

13.50-14.20 **Pedro Lozano:** Green (bio)catalytic processes for sustainable chemical industries, Department of Biochemistry and Molecular Biology, Faculty of Biology, University of Murcia, Spain

14.20-14.35 **Zehranur Tekin:** Enhancing growth profiles of microalgae with a spiral baffle mediated photobioreactor design, Department of Genetics and Bioengineering, Faculty of Engineering, Izmir University of Economics, Türkiye

14.35-14.50 **Marina Tišma:** The role of fungal biotechnology in development of circular and sustainable bioeconomy, Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Croatia

14.50-15.05 **Filippo Bisotti:** A rigorous approach to modelling of biomass gasification, SINTEF Industry, Process Technology, Norway

15.05-15.20 **Anita Šalić:** Maximizing glucose dehydrogenase performance in 3D printed microreactors with various immobilization strategies, University of Zagreb Faculty of Chemical Engineering and Technology, Croatia

15.20-15.35 **Elena Klarić:** Physicochemical and microstructural characterization of bacterial nanocellulose obtained by kombucha watermelon rind fermentation, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

15.35-15.55 **INSEL LAB d.o.o. sponsored lecture ERLAB FILTRATION SYSTEM**

15.45-16.30 COFFEE BREAK

15.45-16.30 **Poster presentations (SESSIONS A&B)**

18:00 CITY TOUR

8.00-9.00 **Registration**

Lectures & Parallel sessions

CONFERENCE HALL MARKET1

Hotel International

SESSION C: GREEN TECHNOLOGIES - *continues*

CHAIRS: M. Cvjetko Bubalo, M. Tišma

9.00-9.30 **Polona Žnidaršić** Plazl: Flow Biocatalysis as a key green technology, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Slovenia

9.30-9.50 **Florian Csarman:** Playing with fire – controlling the (self)-destructive reaction mechanism of lytic polysaccharide monooxygenase, University of Natural Resources and Life Sciences, Department Department of Food Science and Technology, Institute of Food Technology, Austria

9.50-10.05 **Marcelina Mazur:** The use of deep eutectic solvents in microbial reduction and chemo-enzymatic oxidation processes, Department of Food Chemistry and Biocatalysis, Wrocław University of Environmental and Life Sciences, Poland

10.05-10.20 **Mia Radović:** Customizing a microreactor for continuous biocatalysis: enzymatic acetophenone reduction in a deep eutectic solvent, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

10.20-10.35 **Lucija Markulin:** eDNA Labs - Applications of environmental DNA in water quality monitoring (Labena d.o.o. sponsored lecture)

CONFERENCE HALL MARKET2

Hotel International

SESSION D: URBAN FOREST AND URBAN GREENING

CHAIRS: S. Krajter Ostoić, Y. Hoshika

9.00-9.30 **Pierre Sicard:** The 3-30-300 Rule Compliance. A Geospatial Tool for Urban Planning, ACRI-ST, France

9.30-9.45 **Yasutomo Hoshika:** Modeling for optimal tree species selection considering air pollution removal capacity in urban ecosystems -FlorTree-, National Research Council Research Institute on Terrestrial Ecosystems, Italy

9.45-10.00 **Monika Kamenečki:** Overview of plant types for extensive green roofs, University of Zagreb Faculty of Agriculture, Croatia

10.00-10.15 **Maks Udov:** Sustainable management of existing urban trees by impact of soil improvement applied to root systems on trees vitality - research findings, Arbofield d.o.o., Herbafarm-magnolija d.o.o., Croatia

10.15-10.30 **Emiliano Mori:** The bio-bat project assessing bat diversity in central Italy urban-rural interface, National Research Council Research Institute on Terrestrial Ecosystems, Italy

10.30-10.45 **Silvija Krajter Ostoić:** Public involvement in planning, management and maintenance of trees, forests and green space in urban areas – attitudes of professional in 10 European countries, Croatian Forest Research Institute, Croatia

10.40-11.30 **COFFEE BREAK**

10.40-11.30 **Poster presentations (SESSIONS A, C, D&E)**

CONFERENCE HALL MARKET1

Hotel International

SESSION C: GREEN TECHNOLOGIES - *continues*

CHAIRS: J. Vladić, N. Fernández

11.30-11.50 **Ana Rita C. Duarte:** Natural deep eutectic systems applications in polymer engineering, LAQV-REQUIMTE, Chemistry Department, NOVA School of Science and Technology, Portugal

11.50-12.05 **Abdullah Bilal Öztürk:** Utilization scenarios of whey for affordable and clean biochemicals and biofuels. A comparative process simulation and techno-economic evaluation, Department of Chemical Engineering, Faculty of Chemical and Metallurgical Engineering, Yildiz Technical University, Türkiye

12.05-12.20 **Rita Craveiro:** Biopolymeric membranes containing DES for transdermal drug delivery applications, LAQV-REQUIMTE, Chemistry Department, NOVA School of Science and Technology, Portugal

12.20-12.35 **Ana Rita Jesus:** Deep eutectic systems. paving the way for a greener pharmaceutical industry, LAQV-REQUIMTE, Chemistry Department, NOVA School of Science and Technology, Portugal

12.35-12.50 **Martina Bagović Kolić:** Deep eutectic solvents for enhanced drug solubilisation advancing from solvents to delivery systems, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

CONFERENCE HALL MARKET2

Hotel International

SESSION A: ENVIRONMENT AND CLIMATE CHANGES - *continues*

CHAIRS: H. Marjanović, D. Ugarković

11.30-11.45 **Damir Ugarković:** Climatic variations in the Eu-Mediterranean area in Croatia, University of Zagreb Faculty of Forestry and Wood Technology, Croatia

11.45-12.00 **Saeedeh Eskandari:** Mapping the land uses in protected areas of Spain using high-resolution satelite images and random forest model (a case study in Ons island), University of Vigo, Hydro-Forestry Geomodeling Research Group, School of Forestry Engineering, Spain

12.00-12.15 **Želimir Kurtanjek:** Causal AI modelling and prediction of forest fires in Mediterran, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

12.15-12.30 **Doroteja Bitunjac:** Validation of the Biome-BGCMuSo model for estimating soil organic carbon changes in oak chronosequence in Croatia, Croatian Forest Research Institute, Croatia

12.30-12.45 **Andro Kokeza:** Accuracy Assessment of Personal Laser Scanning Estimates of the Main Tree Attributes in Vegetation and Non-Vegetation period in Mixed Common Beech Forest Croatian Forest Research Institute, Croatia

13.00-14.00 **LUNCH**

Lectures & Parallel sessions

CONFERENCE HALL MARKET1

Hotel International

SESSION C: GREEN TECHNOLOGIES - *continues*

CHAIRS: A. R. C. Duarte, K. Radošević

14.00-14.20 **Jelena Vladić:** Evaluation of deep eutectic solvents for enhanced polyphenol extraction and antibacterial activity of Hypericum androsaemum extracts, LAQV-REQUIMTE, Chemistry Department, NOVA - School of Science and Technology, Portugal

14.20-14.35 **Aleksandra Grudniewska:** Extraction of proteins and phenolics from agro-industrial by-products using deep eutectic solvents, Wroclaw University of Environmental and Life Sciences, Poland

14.35-14.50 **João P. Baixinho:** Winery by-products as potential source of novel fungicides, iBET, Institute of Experimental Biology and Technology, Portugal

14.50-15.05 **Iva Čanak:** Removal of aflatoxin b1 using brewer's spent grain, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

15.05-15.20 **Klodian Xhanari:** Corrosion inhibition performance of Arundo donax l. Leaves alcoholic extract on Fe B500B steel in acidic solution, University of Tirana, Faculty of Natural Sciences, Albania

CONFERENCE HALL MARKET2

Hotel International

SESSION E: SUSTAINABLE WOOD PRODUCTS

CHAIRS: M. Klarić, A. Straže

14.00-14.30 **Aleš Straže:** Use of non-destructive methods to determine quality along the entire production chain from forest to end use, University of Ljubljana, Biotechnical Faculty, Department of Wood Science and Technology, Slovenia

14.30-14.45 **Matteo Gilardi:** Design of a novel process for biomethane production via thermochemical conversion of woody biomass, SINTEF Industry, Norway

14.45-15.00 **Claudio Del Menezzi:** Properties of wood laminated composites bonded with citric acid-based adhesive, Department of Forestry Engineering, University of Brasilia, Brazil

15.00-15.15 **Branko Ursić:** Fuel properites of paulownia rbtc15 clone, University of Zagreb Faculty of Forestry and Wood Technology, Croatia

15.20-16.00 **COFFEE BREAK**

15.20-16.00 **Poster presentations (SESSIONS A, C, D&E)**

19.30 **GALA DINNER**

8.00-8.45 **Registration**

Lectures & Parallel sessions

CONFERENCE HALL MARKET1

Hotel International

WORKSHOP: Opportunities and Constraints of Forest Restoration and Prestoration

CHAIRS: M. Đodan, S. Schueler

8.30-8.50 **Silvio Schueler:** Maintaining forest ecosystems in climate change by assisted migration: concepts, benefits and challenges for European forestry, Austrian Research Centre for Forestry, Austria

8.50-9.10 **Martina Đodan:** Restoration needs and constraints in the Republic of Croatia, Croatian Forest Research Institute, Croatia

9.10-09.25 **Ivan Horvat:** Restoration of pedunculate oak stands – the importance of provenance selection, Croatian Forest Research Institute, Croatia

09.25-9.40 **Barbara Škiljan:** Prestoration of popular plantations within cross-border cooperation of Croatia and Serbia, Croatian Forest Research Institute, Croatia

9.40-9.55 **Andrija Barišić:** Establishment and development of Laboratory for Adapted Forest Reproductive Material (LABADAPT), Croatian Forest Research Institute, Croatia

9.55-10.10 **Sanja Perić:** Pedunculate oak management – contemporary challenges and restoration constraints in the Republic of Croatia, Croatian Forest Research Institute, Croatia

10:10-10:45 **Plenary discussion**

10.30-11.00 **COFFEE BREAK**

10.30-11.00 **Poster presentations (SESSION F)**

CONFERENCE HALL MARKET2

Hotel International

WORKSHOP: Development of New Generation of Snack Food for Consumers with Specific Dietary Needs using 3D Printing Technologies ("3DSnack4Health", HRZZ-IP-2020-02-3829)

CHAIRS: D. Novotni, A. Pilipović, N. Čukelj Mustač

8.45-9.00 **Dubravka Novotni:** Development of 3D-printed snacks for consumers with specific dietary needs, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

9.00-9.15 **Kristina Radoš, Bojana Voučko:** Hydrocolloids and enzymes application for improvement of 3D-printability and stability of gluten-free batter and snacks, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

9.15-9.30 **Ana Pilipović:** PROJECT 3Dsnack4health – What we need to know about 3D food printing?, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, Croatia

9.30-9.45 **Mislav Tujmer:** Design and features of a 3D printer for making cereal snacks, University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, Croatia

9.45-10.00 **Maja Benković:** Predicting 3D print snack quality using artificial neural networks (ANN) and rheological data, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

10.00-10.15 **Matea Habuš:** The potential of using grain by-product in the development of 3D-printed snacks, Križevci University of Applied Sciences, Croatia

10.15-10.30 **Nikolina Čukelj Mustač:** Post-processing and flavouring effects on quality of 3D gluten-free snacks, University of Zagreb Faculty of Food Technology and Biotechnology, Croatia

10.30-11.00 **COFFEE BREAK**

10.30-11.00 **Poster presentations (SESSION F)**

CONFERENCE HALL MARKET1

Hotel International

SESSION F: SILVICULTURE AND ECOSYSTEM MANAGEMENT

CHAIRS: V.-N. Nicolescu, A. Đuka

11.15-11.45 **Valeriu-Norocel Nicolescu:** "Stand silviculture" vs. "free-growth silviculture" in sessile oak [Quercus petraea (matt.) liebl], Transilvania University of Brasov, Romania

11.45-12.00 **Srdjan Keren:** How dynamic are structural and compositional changes at a fine-scale level? An example from the strictly protected forests of Roztocze National Park in Poland, Faculty of Forestry, University of Agriculture in Krakow, Poland

12.00-12.15 **Mislav Vedriš:** Damage to narrow-leaved ash (*Fraxinus angustifolia* vahl) and green ash (*Fraxinus pennsylvanica* marshall) in relation to tree attributes and stand structure in Croatian lowland forests, University of Zagreb Faculty of Forestry and Wood Technology, Croatia

12.15-12.30 **Jelena Kranjec Orlović:** Fungi associated with crown dieback of Quercus robur L. In Eastern Croatia, University of Zagreb Faculty of Forestry and Wood Technology, Croatia

12.30-12.45 **Krešimir Krapinec:** Developing prediction model for brown bear timber damages. a case of unpredictability, University of Zagreb Faculty of Forestry and Wood Technology, Croatia

12.45-13.00 **Priyanka Chaudhary:** Unveiling the connection. landscape characterisation, forest health and leopard population in northern aravalli landscape, India, University School of Environment Management, India

13.00-14.00 **LUNCH**

CONFERENCE HALL MARKET2

Hotel International

EIT FOOD HUB WORKSHOP: COMMERCIALIZATION OF SCIENTIFIC RESEARCH RESULTS (in Croatian language)

10.30-11.30 **Identification of Market Needs**

11.45-12.30 **Intellectual Property Protection**

12.30-13.15 **Business Model Development: Desirability**

13.35-15.05 **Business Model Development: Feasibility and Sustainability**

15.15-16.15 **Funding Opportunities**

16.15-16.30 **Presentation of Results**

CONFERENCE HALL MARKET1

Hotel International

SESSION F: SILVICULTURE AND ECOSYSTEM MANAGEMENT *- continues*

CHAIRS: D. Vuletić, S. Posavec

14.00-14.15 **Sushma Rani:** Analysis of Land Use and Land Cover Dynamics in Damdama Wetland, Gurugram, India Using Multiple Change Detection Methods, University School of Environment Management, India

14.15-14.30 **Dijana Vuletić:** Role of living labs in integrating societal demands with biodiversity conservation, Croatian Forest Research Institute, Croatia

14.30-14.45 **Prabhakar:** The role of rubber plantations in ecosystem management: insights from CO_2 sequestration in Tripura, University School of Environment Management, GGSIP University, India

14.45-15.00 **Aman Mahajan:** Neem tree improvement for the development of sustainable bioeconomy and livelihood of farmers, Forest Research Institute Dehradun, India

15.15-15.30 **CLOSING CEREMONY**

Poster Presentations

Session A

Tuesday, 3rd December 2024

AP1 **Marko Bačurin, Ida Katičić Bogdan, Saša Bogdan:** The different timing of exposure to drought stress differentially affects growth in pedunculate oak

AP2 **Martina Kadoić Balaško, Tatjana Masten Milek, Luka Basrek:** Invasion dynamics of Himalayan balsam along the Bregana river

AP3 **Joshal Kumar Bansal, Ajanta Goswami:** Assessment of climate extremes in Himachal Pradesh: analysis of key climate indices and their implications for regional vulnerability

AP4 **Nevenka Ćelepirović, Sanja Novak Agbaba:** Investigation of the presence of other harmful organisms on samples collected for the purpose of special surveillance of the quarantine harmful organism - Geosmithia morbida

AP5 **Saeedeh Eskandari, Carolina Acuña-Alonso, Xana Álvarez Bermúdez:** Effect of climate change on increasing establishment of invasive plant species: an important challenge for biodiversity of native species in changing world

AP6 **Arushi Jha, Naresh Chandra Gupta, Joshal. K Bansal:** Hydro-climate extremes in the Himalayan watershed: a case of the Gandak watershed

AP7 **Mia Marušić, Nenad Potočić, Ivan Seletković, Valentina Lovrić, Krunoslav Sever:** Fertilization enhances drought resilience and recovery of photosynthesis in European beech saplings

AP8 **Saša Orlović, Dragica Stanković, Lazar Kesić, Marina Milović, Saša Pekeč, Leopold Poljaković Pajnik, Branislav Kovačević:** Early selection of most appropriate poplar and willow cultivars for landfill remediation using plant physiology parameters

AP9 **Tanu Prakash, Tuisem Shimrah:** Evaluating the relationship between land surface temperature and different land indices in South Delhi using landsat data

AP10 **Krunoslav Sever, Antonia Vukmirović:** Drought impact on photosynthetic pigments in common beech and sessile oak leaves

AP11 **Mirjana Stanišić, Jelena Nedeljković, Dragan Nonić:** Enhancing climate change governance in Serbia: strategic and legal framework in forestry and related sectors

AP12 **Marko Vucelja, Linda Bjedov, Lea Katarina Gobec, Milan Pernek, Tomislav Dubravac, Dinka Matošević, Darko Pleskalt, Josip Margaletić:** "To monitor, prevent and protect!" – five years of rodent monitoring at forest administration "Vinkovci"

Session B

Tuesday, 3rd December 2024

BP1 **Tomislav Bosiljkov, Anica Bebek Markovinović, Maria Peteh, Sven Karlović, Damir Ježek, Filip Dujmić, Marko Škegro and Danijela Bursać Kovačević:** Determination of rheological properties in functional jelly products based on strawberry and strawberry tree fruit

BP2 **Maja Dent, Igor Jerković, Antonela Ninčević Grassino:** Hydrolate fraction of coffee and coffee by-products as a source of volatile compounds

BP3 **Xhulieta Hamiti, Gjyliza Shallari, Pranvera Lazo:** Phenolic content and physicochemical properties of some albanian honey samples for therapeutic use

BP4 **Maja Jukić Špika, Mirella Žanetić, Gvozden Dumičić, Jakša Rošin, Elda Vitanović:** Influence of common copper fungicides and low-copper products used in olive disease control on olive oil quality

BP5 **Dora Bošnjak, Marija Sigurnjak Bureš, Luna Maslov Bandić:** Impact of chitosan edible covering on the carotenoid composition of mandarin fruit during

BP6 **Antonela Ninčević Grassino, Sandra Pedisić, Maja Dent:** Hydrolate fractions of coffee and coffee by-products as a source of phenolic compounds

BP7 **Matija Maltarski, Anja Damjanović, Marina Miklenić Svetec, Marko Obranović, Kristina Radošević, Višnja Gaurina Srček, Igor Slivac:** Flaxseed protein hydrolysates enhance lipid accumulation in adipocyte

BP8 **Nataša Mikulec, Fabijan Oštarić, Iva Horvat Kesić, Nevijo Zdolec, Jasminka Špoljarić:** Production of an innovative functional food supplement based on goat's milk

BP9 **Mojca Čakić Semenčić, Tea Žugec, Filip Šupljika:** Spectrofluorimetric determination of the riboflavin content in energy drinks

BP10 **Paula Šiptar, Tereza Čabrilo, Višnja Stulić, Irena Barukčić Jurina, Zoran Herceg, Tomislava Vukušić Pavičić:** Challenges in developing 3D-printed functional fruit and dairy products. WORKSHOP: Development of New Generation of Snack Food for Consumers with Specific Dietary Needs using 3D Printing Technologies ("3DSnack4Health", HRZZ-IP-2020-02-3829)

Session C

Wednesday, 4th December 2024

CP1 **Maja Drenovac, Ana Jurinjak Tušek, Davor Valinger, Tamara Jurina, Jasenka Gajdoš Kljusurić, Maja Benković:** Influence of Melissa officinalis extract concentration on biosynthesis of iron nanoparticle

CP2 **Mirna Brekalo, Blanka Bilić Rajs, Sandra Budžaki, Marta Ostojčić, Ivica Strelec:** Production of Cellulose-Based Enzyme Immobilization Carrier from Brown Onion Skin

CP3 **Ivona Karaula, Emma Karolina Vasung, Anja Damjanović, Manuela Panić, Kristina Radošević, Marina Cvjetko Bubalo:** Rational design of natural deep eutectic solvents for extraction of high-value broccoli compounds

CP4 **Luka Brezinščak, Iva Ćurić, Željka Zgorelec, Marija Galić, Davor Dolar:** Effect of textile wastewater usage on zinc concentration in soil

CP5 **Maja Dent, Dolores Šaško:** Ultrasound - assisted extraction of phenolic compounds from olive leaves

CP6 **Naiara Fernández, Frédéric B. Gaspar, Ana Luísa Oliveira, Mário Vale, Margarida Pimenta, João P. Baixinho, Sara Tedesco, Maria Teresa Barreto Crespo:** Evaluation of olive oil industry by-products as a source of phytosanitary ingredients

CP7 **Jasna Halambek, Mario Vereš, Nina Popović, Sandra Zavadlav:** Inhibition of steel corrosion in hydrochloric acid solution using chitosan and caffeine

CP8 **Ana Huđek Turković, Karla Hanousek Čiča, Ena Cegledi, Ksenija Durgo, Jasna Mrvčić, Damir Stanzer, Verica Dragović-Uzelac:** Evaluation of the antimicrobial, antiproliferative, and antioxidative activity of blackcurrant and bilberry leaf extracts obtained by the green approach of accelerated solvent extraction

CP9 **Stela Jokić, Krunoslav Aladić, Ana-Marija Cikoš, Ivana Flanjak, Igor Jerković, Sanja Radman, Drago Šubarić, Rozelindra Čož-Rakovac:** Isolation of pigments from brown macroalgae Cystoseira corniculata, Ericaria crinita and Gongolaria barbata

CP10 **Antonija Jurić, Marin Ugrina, Damir Barbir, Ivona Nuić:** A sustainable approach to the disposal of mercury-saturated fes-doped natural zeolite by solidification/ stabilization in a cement matrix

CP11 **Nemanja Krgović, Jelena Živković, Milica Radan, Miloš Jovanović, Katarina Šavikin, Dejan Pljevljakušić:** Natural deep eutectic solvents for sustainable extraction of lignans from burdock seeds

CP12 **Mojca Čakić Semenčić, Katarina Marević, Anja Rašić, Filip Šupljika, Mia Kurek:** Influence of microwave extraction parameters on the total polyphenols and antioxidant capacity of borage and lemon balm extracts

CP13 **Nikolina Račić, Lana Vujanić, Jasmina Lapić, Anica Bebek Markovinović, Danijela Bursać Kovačević, Senka Djaković:** Characterization of bioactive compounds in the extract of the fruit and leaf of *Arbutus unedo* l. (the strawberry tree)

CP14 **Franka Markić, Višnja Stulić, Tomislava Vukušić-Pavičić, Nadica Maltar-Strmečki:** Isolation of bioactive compounds from vegetable by-products using a pulsed electric field as pre-treatment

CP15 **Jovan Parlić, Gordana Stevanović, Marija Ajduković, Zorica Mojović, Nataša Jović-Jovičić:** Activated sawdust derived biochar for adsorption of dyes

CP16 **Marijan Logarušić, Marina Cvjetko Bubalo, Anja Damjanović, Marko Božinović, Polona Žnidaršič-Plazl, Igor Plazl, Mia Radović, Ivana Radojčić Redovniković:** The role of deep eutectic solvents in enhancing sustainability and efficiency in biocatalytic processes

CP17 **Angela Matanović, Ana Slišković, Marina Svetec Miklenić, Ivan-Krešimir Svetec:** Genetic modification of non-conventional yeast Scheffersomyces stipitis for lactate production

CP18 **Aleksandra Jovanović, Nemanja Krgović, Ana Alimpić Aradski, Jelena Živković, Katarina Šavikin:** Polyphenol and protein content in wild thyme dust extracts with natural deep eutectic solvents

CP19 **Natalija Velić, Marija Stjepanović, Maja Zovko, Zita Šereš, Nikola Maravić, Marek Wrobel, Marcin Jewiarz:** Biosorption Potential of buckwheat hulls biochar functionalized with H2SO4 and FeCl3 for phosphate removal from wastewater

CP20 **Renata Vičević, Anita Šalić, Ana Jurinjak Tušek, Bruno Zelić:** Kinetic Modeling of Ralstonia eutropha H16 Growth on Different Media

CP21 **Siniša Simić, Aleksandra Gavarić, Igor Jerković, Stela Jokić, Krunoslav Aladić, Zoran Maksimović, Senka Vidović:** Exploring the potential of pannonian thyme (Thymus pannonicus all.): supercritical CO_2 extraction for the recovery of low polar fraction

CP22 **Elda Vitanović, Marijana Popović, Filipa Burul, Ana Bego, Luka Čotić, Frank Zalom:** Novel approach to olive fruit fly (Bactrocera oleae, rossi) monitoring and/ or control using volatile compounds produced by brewing by-product

CP23 **Klodian Xhanari, Muhamed Farruku:** Recent advances in plants extracts as green corrosion inhibitors for carbon steel in aggressive solutions

CP24 **Katarina Šavikin, Nemanja Krgović, Miloš Jovanović, Jelena Živković, Aleksandra Jovanović:** Ultrasound-assisted natural deep eutectic solvents extraction of bioactive compounds from rosehip fruits

CP25 **Danijela Urbancl, Lana Gajšt, Darko Goričanec, Sven Gruber, Klemen Rola, Aleksandra Petrovič:** Assessment of the energy potential of flax and hemp by-products

Session A&D

Wednesday, 4th December 2024

AP13 **Ivan Balenović, Krunoslav Indir, Ante Šiljeg, Ivan Marić, Anita Šimić Milas, Danko Kuric, Andro Kokeza:** Testing the performance of the-state-of the-art hand-held personal laser scanning systems for tree height estimations in lowland pedunculate oak forests

AP14 **Damir Ugarković, Matej Knezičić:** The influence of canals in a floodplain forest ecosystem on soil moisture

AP15 **Nikola Zorić, Robert Bogdanić, Ivan Balenović:** Use of thermal images captured from UAV for detecting nests of pine processionary moth in the Lika region, Croatia

DP1 **Laura Bonora, Francesca Martelli, Valentina Marchi:** Informed, aware and communicative young citizens: a strategic approach to address urban greening challenges

DP2 **Vinko Paulić, Branko, Ursić, Darko Bakšić, Dinko Vusić:** Sulfur accumulation in foliage and shoots of small leaved linden urban trees growing near sulfur thermal mineral water springs in town of Varazdinske Toplice, Croatia

Session E

Wednesday, 4th December 2024

EP1 **Aleksandar Lovrić, Nebojša Todorović, Vladislav Zdravković, Mimica Stefanović:** Evaluating the potential for exterior use of plywood panels composed of thermally modified popular veneers

EP2 **Aleksandra Lj. Mitrović, Katarina Vojisavljević, Ilinka Pećinar, Dragana Bartolić, Dušica Janošević:** Raman microspectroscopy of "tensile flexure wood" in Populus x Euramericana

Session F

Thursday, 5th December 2024

FP1 **Veronique Decroocq, Dalibor Ballian Katja Sonnenschein, Martin Lascoux, Phil Aravanopoulos:** What is fruitdiv in European initiative about forests fruit

FP2 **Sanja Bogunović, Miran Lanšćak, Zvonimir Vujnović, Nevenka Ćelepirovć, Mladen Ivanković:** In vitro conservation of narrow-leaved ash in Croatia - advantages and risks

FP3 **Branislav Cvjetković, Milan Mataruga, Franciska Deljak, Tatjana Sabljić, Vojislav Dukić:** Characteristics of seeds and seedlings from the marginal population of pedunculate oak (Quercus robur l.) from Livanjsko polje

FP4 **Edin Mešković, Galib Mahmutović, Tarik Treštić, Azra Čabaravdić:** Supervision of spruce bark beetle attacks supported with remote sensing in the north-east Bosnia

FP5 **Milivoj Franjević, Andreja Đuka, Ivica Papa, Ivan Žarković, Kristijan Tomljanović:** Forest pests in aftermath of bark beetle outbreaks in une-ven-aged fir stands

FP6 **Dickson Heisnam, Prodyut Bhattacharya: Analyzing land use land cover (LULC) and NDVI trends in Loktak lake:** insights for ecosystem management and Unesco global geopark designation

FP7 **Sanja Jovanović, Aleksandar Vemić, Aleksandar Lučić, Ljubinko Rakonjac, Vladan Popović:** Bacterial treatment promotes the growth of two-year-old sessile oak (Q. petraea (matt.) liebl) seedlings produced from damaged acorns

FP8 **Martina Kičić, Tamara Kirin, Nikolina Bakšić Pavlović, Blaženka Sopina, Gordana Goreta, Tin Lukačević, Neven Tandarić, Dalia Matijević, Andrea Blažević, Tajana Uzelac Obradović, Tea Šilić, Dijana Vuletić:** Croatian know-how – advancing biodiversity, ecosystem condition and services in various spatial contexts

FP9 **Jelena Kolić, Renata Pernar, Mario Ančić:** Application of remote sensing products in determining damage caused by a storm

FP10 **Bojan Konatar, Branko Kanjevac, Ljubinko Rakonjac, Ilija Đorđević,** Miroslava Marković, Jelena Božović, Miloš Račić: Dynamics of artificial regeneration and establishment of new forests in Serbia for the period 2017-2023

FP11 **Miran Lanšćak, Sanja Bogunović, Anđelina Gavranović Markić, Sanja Perić, Barbara Škiljan, Zvonimir Vujnović, Mladen Ivanković:** Close-to-nature foreSt SusTainablE Management under Climate Changes - LIFE SySTEMiC

FP12 **Peimi Lungleng, Tuisem Shimrah:** Unveiling the cultural significance of traditional shifting agriculture in biodiversity conservation: perspectives of the Tangkhul community of Northeast India

FP13 **Tsuyoshi E. Maruyama, Momi Tsuruta:** Tissue culture-mediated regeneration as a tool for scale-up propagation of selected japanese conifer trees

FP14 **Jelena Nedeljković, Marina Nonić, Dragan Nonić:** Female students' perspectives on forestry careers in Serbia

FP15 **Emanuel Gaši, Katarina Hančević, Mate Čarija, Tomislav Radić:** Mycorrhizal networking between grapevine roots in biotic stress context: impact on physiology of healthy grapevine

FP16 **Mirsada Starčević, Galib Mahmutović, Azra Čabaravdić:** Trends in forest cover based on sentinel S2 imagery in protected area "Tajan"

FP17 **Neven Tandarić, Tin Lukačević, Mihaela Meštrović:** Planning green infrastructure in Croatia: current state and challenges

FP18 **Lucija Bužančić, Dora Tomić Reljić:** Landscape ecology analysis of the Korenica hunting ground

FP19 **Kristijan Tomljanović, Marko Augustinović, Tomislav Turajlija, Marijan Grubešić:** Daily – seasonal activity of wild cat in the area of Plitvice lakes national park

FP20 **Marta Ljevar, Dora Tomić Reljić:** Identification of landscape values of the municipality Kaptol

FP21 **Nenad Potočić, Tom Levanič, Srđan Stojnić, Valentina Lovrić, Ivan Seletković, Tamara Jakovljević, Krunoslav Indir, Mia Marušić, Nikola Zorić, Robert Bogdanić, Primož Simončič, Aleksander Marinšek, Lazar Kesić:** enhancing forest monitoring of oak forests in South-East europe - oaks

Plenary Talks

RETHINKING ECONOMIC GROWTH: HOW FORESTS CAN LEAD US TO A SUSTAINABLE FUTURE

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KEYWORDS:
economic model, ecosystem services, forests, renewable resources, sustainable development

To achieve a truly sustainable future, we must fundamentally rethink our economic models. Traditional frameworks, often focused on GDP as a primary measure of success, prioritize short-term growth and resource extraction over long-term resilience and ecological balance. This approach frequently overlooks the vital services provided by natural ecosystems, especially forests, which are essential for human survival and environmental health. Forests play a critical role in this necessary transformation. They act as carbon sinks, absorbing CO_2 and helping mitigate climate change, while also regulating water cycles and supporting biodiversity. In addition to these essential functions, forests provide renewable resources, such as wood, which can replace fossil-based materials in construction, manufacturing, and energy production. This shift not only reduces carbon emissions but also fosters a circular economy, where materials are reused and sustainably managed. The multifaceted benefits of forests extend beyond environmental metrics. They support livelihoods, provide recreational opportunities, and enhance community well-being. However, our current economic systems often fail to capture these broader benefits, leading to unsustainable practices that prioritize immediate profits over the long-term health of our planet. To fully harness the potential of forests, we must adopt policies that promote sustainable forest management and restoration initiatives. This includes investing in nature-based solutions and creating incentives that reflect the true value of ecosystem services. By embracing more inclusive economic frameworks that recognize the interconnectedness of ecological integrity, social equity, and economic prosperity, we can redefine success in a way that benefits both people and the planet. Research plays a crucial role in this process by generating data-driven insights and innovative solutions to inform policy decisions. This evidence-based approach can help create effective incentives that reflect the true value of ecosystem services. Ultimately, embedding forest preservation within a broader agenda for systemic change will safeguard these critical resources and pave the way for a future where progress is measured not just in economic terms, but by the health and sustainability of our environment and communities.

THE INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS (IUFRO)

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KEYWORDS:
forest research, international collaboration, networking

IUFRO is a non-profit, non-governmental, non-discriminatory international network of forest scientists, which promotes global cooperation in forest-related research and enhances the understanding of the ecological, economic and social aspects of forests and trees. IUFRO is "the" global network for forest science cooperation, dating back to 1892. IUFRO aims to contribute to achieving the Sustainable Development Goals set by the United Nations. It unites more than 15,000 scientists in around 630 Member Organizations in almost 120 countries. Scientists cooperate in IUFRO on a voluntary basis. The network is open to all individuals and organizations dedicated to forest and forest products research and related disciplines, open to all individuals and organizations involved in forest research and forest related sciences. IUFRO attains its objectives by networking activities including the generation, exchange and dissemination of scientific knowledge and practices; by the provision of access to relevant information, and the assistance to scientists and institutions to strengthen their research capacities. The vision of IUFRO is to be "The Global Voice of Forest Science Promoting a Sustainable Future of Forests and Society". IUFRO's mission is to advance research excellence and knowledge sharing, and to foster the development of science-based solutions to forest-related challenges for the benefit of forests and people worldwide. Seventy meetings are held on average every year. IUFRO World Congresses take place every 4-5 years. The last one was in June 2024 in Stockholm Sweden, the next one will be in 2029 in Nairobi Kenya. One can join any of the 9 scientific Divisions, over 50 Research Groups, more than 180 Working Parties and 9 interdisciplinary Task Forces. Get in touch with any of the almost 800 voluntary coordinators of these units. You can also take part in activities of IUFRO's Special Programmes and Projects: Special Programme for Development of Capacities (IUFRO-SPDC); Science-Policy Programme (SciPol); Special Programme Directors' Forum (IUFRO-SPDF); Project on World Forests, Society and Environment (IUFRO-WFSE).

AIR POLLUTION AND CLIMATE CHANGE IMPACTS ON FORESTS

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KEYWORDS:
air pollution, climate change, ecosystem, forest, impacts

The impacts of air pollution and climate change on ecosystems have been investigated in many studies in the last decades. These studies showed, for example, that climate change has already affected plant distribution, or that nitrogen deposition has large impacts on ecosystem species composition. Impacts of climate change and air pollution on ecosystems interact in two basic ways: (a) climate change can modify the effects of exposure of ecosystems to air pollution, and vice versa; (b) air pollution can change sensitivity of ecosystems to specific impacts of climate change. The exposure of ecosystems to air pollution can change as a result of phenological changes induced by climate change (e.g., changes in the length of the growing season) as well as by altered spatial and temporal distribution of air pollutants through new weather patterns. Their sensitivity may change as a result of, inter alia, climate-induced changes in ecosystem vitality, soil processes and biodiversity. There is an increasing awareness in both the science and policy communities of the importance of addressing the linkages between the traditional air pollutants and greenhouse gases. Many air pollutants and greenhouse gases have not only common sources, but also their emissions interact in the atmosphere, and may join to cause a variety of environmental impacts on the local, regional and global scales.

ENZYMES CONTRIBUTING TO SUSTAINABLE FOOD PRODUCTION

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KEYWORDS:
forest research, international collaboration, networking

Enzymes have a long history in the production of food. Based on well-known traditional processes, new applications in food technology have been developed, including enzymes for the hydrolysis of polymers, the synthesis of oligomers, removal of off-flavors and other compounds, generation and synthesis of flavor compounds, and processing aids. Recent developments indicate that the use of enzymes in food processes is becoming more diverse and multifaceted than just food modification. Examples include the extraction of nutritious components from agricultural residues, texture modification or process monitoring by enzymatic biosensors capable of detecting and quantifying analytes in complex matrices. The lecture illustrates these trends by presenting different enzymes and engineered enzymes that have the potential to generate and extract prebiotic oligosaccharides, change the viscosity of heteropolysaccharides, or detect mono- and disaccharides produced in food processes. Lytic polysaccharide monooxygenases (LPMOs) can degrade a wide variety of polysaccharides such as cellulose, starch, chitin, xyloglucans, glucans and pectins. With these diverse substrate specificities, LPMOs can release a variety of mono- and oligosaccharides from plant biomass that can be used as gelling agents and prebiotics. Cellobiose dehydrogenases (CDHs) oxidize mono- and oligosaccharides to aldonic acid. Besides their biocatalytic application, they can also be used in aperometric biosensors for the detection of glucose, lactose, maltose and other carbohydrates. The application of CDH biosensors in the production of dairy and non-dairy products highlights the potential for process monitoring and control to support sustainable food production.

GREEN (BIO) CATALYTIC PROCESSES FOR SUSTAINABLE CHEMICAL INDUSTRIES

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KEYWORDS:
Applied Biocatalysis, Green Chemistry, Ionic Liquids, Supercritical Fluids, Sustainable Processes

Green Chemistry Principles constitutes the best-guiding philosophy for reducing pollution and safeguarding the environment, providing us with enough tools to design sustainable transformations and implement industrial processes by means of renewable feedstocks. Our society claims for a re-designing of all the industrial chemical processes should to avoid or minimise waste production, by involving not only selective and efficient catalytic transformations with high atom and energy efficiency, but also clean separation processes using non-toxic and safe products. [1] The greenness of chemical processes turns around two main axes: the selectivity of catalytic transformations, and the separation of pure products. The transfer of the exquisite catalytic efficiency shown by enzymes in nature to chemical processes is an important challenge.[2] The combination of (bio)catalysts with appropriate green/clean reaction systems, such as supercritical carbon dioxide (scCO2),[3] ionic liquids (ILs),[4] deep eutectic solvents (DESs), resulted in synergetic and outstanding platforms for developing (multi)catalytic green chemical processes, even under flow conditions.[2] Green chemistry and circular economy principles can constitute the most important and efficient strategy for achieving many of the 17 Sustainable Development Goals set by the United Nations. This will drive our society to a sustainable future by reducing the consumption of resources and drastically minimising the environmental impact of our recalcitrant wastes. The synthesis of biodiesel, flavours and nutraceutical, as well as the capture and transformation of carbon dioxide, and the plastic waste depolymerization are some of the successful green chemical processes presented here.

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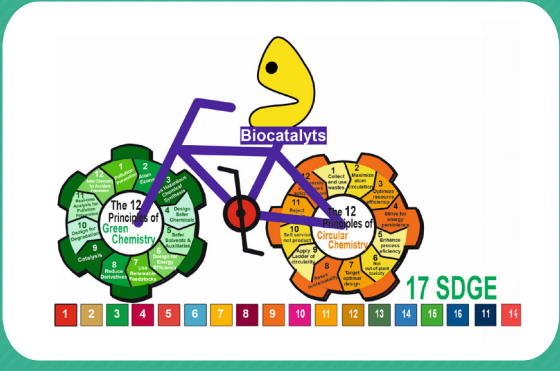

Fig. 1. From green to circular chemistry paved by biocatalysis. [1]

FLOW BIOCATALYSIS AS A KEY GREEN TECHNOLOGY

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KEYWORDS:
biocatalysis, continuous processes, biocatalyst immobilization

Biocatalytic processes offer transition to more sustainable manufacturing of food, chemicals, pharmaceuticals, and biofuels, especially when starting from the bio-based resources. Development of continuous processes with immobilized enzymes or cells, i.e. flow biocatalysis, and implementation of green solvents further contributes to lower environmental footprint and cost effectiveness of the processes. Examples of efficient biocatalytic processes development comprising enzyme and substrate screening, medium engineering, and biocatalyst immobilization to intensify biocatalytic processes will be presented.

THE 3-30-300 RULE COMPLIANCE: A GEOSPATIAL TOOL FOR URBAN PLANNING

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KEYWORDS:
Green space, Green infrastructure, Classification, City planning, Remote sensing, Satellite imagery, WorldView-2, Pléiades

As the global urban population is expected to reach 70% by 2050, sustainable urban planning is essential for creating resilient and livable cities. Urban trees and green spaces are vital for mitigating climate change and enhancing public health. The 3-30-300 rule, introduced in 2021, mandates that every citizen should see at least three mature trees from their home, live in neighborhoods with at least 30% tree canopy cover, and be within 300 meters of a high-quality green space. Despite its significance, practical methods for measuring and evaluating this rule have been lacking. To address this gap, we developed a geospatial tool using remote sensing and Geographic Information System (GIS) techniques to assess compliance with the 3-30-300 rule. The tool employs very-high-resolution satellite imagery for detecting trees and estimating canopy cover (Components 3 and 30) and integrates OpenStreetMap data to assess proximity to green spaces (Component 300). We applied this tool to two study areas: Aix-en-Provence (France) and Florence (Italy). In Aix-en-Provence, 68% of buildings met the tree visibility requirement, compared to 38% in Florence. For canopy cover, 94% of buildings in Aix-en-Provence met the 30% criterion, versus 10% in Florence. Regarding proximity to green spaces, 27% of buildings in Aix-en-Provence were compliant, compared to 41% in Florence. Overall, Aix-en-Provence had 18% of buildings compliant with all three components, while Florence had only 4%. Field validation in Aix-en-Provence showed high accuracy, with 98% for Component 3 and over 90% for Component 300. Limitations include challenges in rural areas due to wildfire management and potential inaccuracies in measuring distances to green space entrances.

USE OF NON-DESTRUCTIVE METHODS TO DETERMINE QUALITY ALONG THE ENTIRE PRODUCTION CHAIN FROM FOREST TO END USE

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KEYWORDS:
forest-wood chain, non-destructive methods, quality assessment, sustainable practices, wood demand

Global demand for wood is expected to increase significantly due to population growth and economic expansion, particularly in the rapidly developing regions of the world. To meet demand, the forest industry must adopt sustainable practices and innovative technologies that are critical to ensuring that forests continue to provide important environmental services, sequester carbon and produce timber.

Several cutting-edge technologies play an important role in improving timber production and distribution. Aerial and satellite remote sensing, such as LiDAR, enables precise mapping and monitoring of forest resources, providing detailed data on structure, biomass and condition. Ground-based scanning technologies such as laser scanning and photogrammetry provide information on tree characteristics and timber quality. In addition, X-ray and NMR scanning and FT-IR spectroscopy are highlighted as valuable tools for assessing wood properties and detecting defects. These technologies provide detailed images of the internal structure of logs and reveal defects such as knots and cracks, provide information on the chemical composition of the wood and are even able to identify different types of wood and their properties. Finally, various acoustic technologies are available to measure the speed of sound in wood, which correlates with the density and stiffness of the wood, and even 3D acoustic tomographs can be used to assess the internal characteristics of standing trees.
The study compares the available non-invasive methods in the forest-wood chain in terms of their technological complexity, information provision and affordability. The study includes examples of non-destructive quality monitoring from standing trees to forest wood assortments and products such as sawn timber and glued laminated timber. The results of the assessment and classification are presented and compared with standard methods and laboratory tests. The study also demonstrates the applicability of some non-invasive techniques in timber practice.

STAND SILVICULTURE" VS. "FREE-GROWTH SILVICULTURE" IN SESSILE OAK [*QUERCUS PETRAEA* (MATT.) LIEBL]

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KEYWORDS:
diameter increment, epicormic branches, "free—growth silviculture", sessile oak, "stand silviculture"

A small-scale R&D project, including four plots (P1...P4) of 300 sq.m., was established in March 2019 in a 25-year-old sessile oak-dominated stand (sub-compartment 98C, Forest Management Unit I Saliste, Valea Frumoasei Forest District), regenerated naturally through group shelterwood cuttings. In each plot, "potential" final crop trees were selected, based on vigour-quality-criteria, and painted. The initial density of stands ranged between 2,600 trees ha-1 (P1) and 3,800 trees ha-1 (P4), while the initial stocking ranged between 24.70 m2 ha-1 (P3) and 29.18 m2 ha-1 (P2). Silvicultural interventions (cleaning-respacings, all of them mostly from below), of very high intensity (56.42-85.56% by number of trees and 33.36-68.54% by basal area) were performed in P1-P3, while P4 was kept as control. In plots no. 1 and 2, a "stand silviculture" (even selecting, but not favouring the "potential" final crop trees) was performed, while trees in P3 were given a "free-growth" state at crown level.
Between 2019 and 2024, the mortality of trees in the four plots ranged between 0% in P3 (with the lowest density – 467 trees ha-1 – and stocking – 7.77 m2 ha-1 in March 2019) and 22.82% in P4 (initial density 3,800 trees-1 ha and stocking - 27.56 m2 ha-1). Sessile oak (a light-demanding species) showed the highest natural mortality, followed by trembling aspen Populus tremula (also light-demanding). In absolute terms, the highest increment of mean arithmetic diameter was recorded in P3 (3.86 cm, 27.40%), followed by P2 (3.38 cm, 27.32%), P1 (2.25 cm, 16.19%), and P4 (0.91 cm, 10.36%). In terms of increment of basal area, P3 (59.07%) showed the highest value in relative terms, while P4 (control) the lowest one (14.73%). The "potential" final crop trees showed high levels of increment of mean arithmetic diameter in P3 (133 trees ha-1 - 4.50 cm, 31.14%) and P2 (233 trees ha-1 - 4.34 cm, 25.72%), the lowest level being found in P1 (264 trees ha-1 – 2.75 cm, 16.78%). Obviously, these trees should be favoured by subsequent thinning from above, concentrated around their crowns or even providing them a "free-growth" state at crown level. Even showing the best results in terms of increment of basal area and mean arithmetic diameter, trees in P3 ("free-growth" state) showed a high share of epicormic branches in 2024, as a result of sudden opening of canopy formed by small-sized crowns of trees kept crowded too long.

Session A:

ENVIRONMENT AND CLIMATE CHANGE

ASSESSING FUTURE ISOPRENE EMISSIONS IN SOUTHEAST ASIA: CLIMATE CHANGE IMPLICATIONS

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KEYWORDS:
Isoprene, Climate change, Southeast Asia, WRF, MEGAN

Isoprene emission is known to depend heavily on temperature, and radiation. Considering these environmental factors together is crucial for a comprehensive understanding of the impact of climate change on isoprene emissions and atmospheric chemistry. Therefore, the aim of this study is to investigate how isoprene emission responds to changing climate scenarios in Southeast Asia (SEA). Two climate change scenarios, RCP4.5 and RCP8.5, were used to simulate climate change using the Weather Research Forecasting (WRF v3.9.1) model in three different time periods: near-future (2030-2039), mid-century (2050-2059), and far future (2090-2099), with 2010 (2005-2014) as the baseline period. The output from WRF was then used to investigate how isoprene emission changes under a changing climate by using the Model Emission of Gases and Aerosol from Nature (MEGAN v2.1). The results show that the overall isoprene emissions during the baseline period are 1.41 tons hr-1 during DJF and 1.64 tons hr-1 during JJA. The overall emissions for both RCPs slightly increase during DJF, ranging from 0.03 to 0.06 tons hr-1 in the near-future, 0.11 to 0.19 tons hr-1 in the mid-century, and 0.24 to 0.52 tons hr-1 in the far future. During JJA season, environmental conditions often favour higher emission rates in MEGAN due to their optimal state. Isoprene emissions also show a strong positive correlation (0.81 – 1.00) with temperature and photosynthetic active radiation (PAR). The future emission rate of isoprene is strongly modulated by both temperature and PAR, as indicated by a strong positive correlation (0.81 - 1.00). This relationship underscores the fact that future warming will not be the sole driver impacting isoprene emissions. Therefore, it is essential to consider the multifaceted effect of climate change in shaping the levels of isoprene in the future.

EXPLOITING HYPERSPECTRAL DATA TO PREDICT PHOTOSYNTHESIS AND HYDRIC STATUS RELATED-PARAMETERS AND DISCRIMINATE OZONE (O_3) EFFECTS ON GRAPEVINE (*Vitis vinifera* L.)

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KEYWORDS:
air pollution, digitalization, partial least squares regression, sustainable monitoring, vegetation spectroscopy

The processes of photosynthesis and the hydric dynamics can be leveraged to monitor plant health under stressful environmental conditions. Vegetation spectroscopy emerges as a promising technique for rapid and non-invasive monitoring of numerous plants across different phenological stages. In this study, we assessed the ability of reflectance spectroscopy to predict several leaf traits of grapevine (Vitis vinifera L., cv. Cabernet Sauvignon) related to photosynthesis and water status under increasing levels of ozone (O_3) exposure. Full-range hyperspectral data (i.e., 400-2400 nm) were collected from leaves subjected to three O_3 concentrations: ambient air (AA), moderate O_3 (1.5 × AA), and elevated O_3 (2.0 × AA), at the Free-air O_3 eXposure (FO3X) facility in central Italy. These spectral profiles were combined with measurements of photosynthetic capacity and water use efficiency, inferred from the Bernacchi's and Variable J parametrization models. Predictive models were developed using partial least squares regression (PLSR), and the majority of the parameters were well estimated by PLSR-models (average model goodness-of-fit for validation, R2: 0.40-0.65). Moreover, spectral data allowed to accurately distinguishing plants exposed to elevated O_3 levels with 65% accuracy at the bunch closure stage (BBCH 77), and 72% accuracy at the berry ripening stage (BBCH 83), even before the occurrence of foliar damage induced by O_3 exposure. The findings of the current work establish solid pillars for further investigations, pursuing the aim to develop a rapid and cost-effective phenotyping tool for integration into vineyard monitoring activities, covering both grafted vines and fully developed plants.

OZONE APPLICATION AS A USEFUL TOOL AGAINST CROP DISEASES IN PRE- AND POST-HARVEST

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KEYWORDS:
food safety, green technology, sustainability, decontamination, zero-residuals

The application of ozone (O_3), which is a powerful oxidizing agent with zero residual, represents a promising technology in the management of pre- and post-harvest diseases of crops. Ozone can be dissolved in water (ozonated water; OW) and applied through irrigation, which was shown to stimulate the synthesis of bioactive compounds involved in plant resistance, or can be directly used in its gaseous form (e.g., controlled atmosphere), which appeared effective in fungal decontamination. Here, two examples of O_3 application are reported: (i) OW (400 ppb, 100 mL pot-1, every two days for four weeks) was tested in *Dianthus caryophyllus/Erysiphe buhrii* pathosystem by investigating the plant signalling/antioxidant molecules and the disease severity for three weeks post inoculation (wpi); and (ii) gaseous O_3 (500 ppb, for 30, 60 or 90 minutes) was used for the disinfection of *Cicer arietinum* grains from mycotoxigenic fungi and their metabolites (i.e., aflatoxins and patulin). Immediately after the inoculation, leaves of OW-treated plants showed a salicylic/abscisic acid-mediated response (+70 and +80% respectively, in comparison to controls), whereas flowers showed an ascorbic acid and α-tocopherol accumulation starting from 1 wpi (+50 and +20%, respectively). After 3 wpi, the disease severity decreased in OW treated plants (-45%). Gaseous O_3 significantly decreased the incidence of *Penicillium* spp. (-50%, independently to the time of exposure) and reduced the patulin and aflatoxin contents after 30 minutes (-85 and -100%, respectively). Overall, these results confirm the potential of O_3 application as a useful tool in plant disease management and conservation of crop products.

ION FLUXES IN PRECIPITATION, THROUGHFALL, FOREST FLOOR SOLUTION AND TOPSOIL SOLUTION IN ALEPPO PINE FOREST

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KEYWORDS:
anions, cations, lysimeters, Mediterranean

Ion fluxes in forests are closely linked to the water cycle, as water is the main solvent and medium for the transport of nutrients between the above-ground vegetation and the soil. Furthermore, plants play a crucial role in the ion cycle, which is not only reflected in the adsorption of nutrients, but also in the increase of nutrient content in the soil through the leaching of nutrients from the plant biomass via precipitation. The aim of this study was to evaluate the effects of Aleppo pine forest (Pinus halepensis Miller) on ion fluxes (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH^{4+}, SO_4^{2-}, NO_3^{-} and Cl^{-}). The study was conducted in Central Dalmatia, a region of Croatia, over the period of one year. The climate in the study area is Mediterranean, the predominant forests are Aleppo pine forests and the predominant soil in the plots is Haplic/Leptic Cambisol. The chemical composition in samples of precipitation, throughfall forest floor solution and topsoil solution in the Aleppo pine forest was compared with the chemical composition in the precipitation and topsoil solution of the open field.

The results showed that the total amount of precipitation in 2022 in the open field was higher than in the forest. In addition, more water percolated through the soil in the open field than in through the soil in forest. The concentrations of all ions in the samples collected in the open field were lower compared to the samples collected in the forest, while the pH of the samples in the open field was higher. The ion concentrations in the forest floor solution were significantly higher than in the precipitation and the throughfall.

When comparing forest floor solution samples and topsoil solution samples, it was found that the concentration of all ions except K^{+} and NH_4^{+}, was lower in the forest floor solution than in the topsoil solution samples. This decrease can be attributed to processes taking place in the most biologically active layer, the forest floor layer, where microorganisms assimilate certain ions and bind to the active surface of the forest floor. Throughfall plays an important role in the input of ions into the forest soil by leaching ions from the tree canopy and thus influencing the geochemical cycle. Another important process takes place in the organic layer, where ions are washed out of the organic layer and then enter the mineral layer of the soil. A comparison of the ion fluxes in the Aleppo pine forest with those in the open field shows that the ion concentrations are significantly higher in the samples collected in the forest, which means that the Aleppo pine forest contributes significantly to the ion input into the soil and thus to the nutrients.

ADVANCING GROUNDWATER RECHARGE MONITORING IN KARST AQUIFERS: A HOLISTIC APPROACH

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KEYWORDS:
karst critical zone, hydrological monitoring, groundwater recharge, interdisciplinary study, monitoring network evaluation

Worldwide, karst covers a not insignificant 15 % of the land surface, of which up to a third is forested. This type of land provides numerous ecosystem services and resources, the most important of which is certainly water, which plays a key role in freshwater supply and the preservation of underground biodiversity. As a result of the extreme weather events or other natural disasters that have recently occurred around the world, the impacts on vegetation cover, the water cycle and other natural processes are expected to become more frequent and severe. Understanding the effects of environmental change on karst aquifers — particularly in relation to precipitation, evapotranspiration and infiltration — is crucial for assessing groundwater recharge dynamics. These processes are influenced by changes in soil and vegetation cover and are crucial for the conservation of karst water resources. However, the complex nature of water flow in karst regions complicates the assessment of groundwater recharge, particularly due to the challenges presented by measurement and sampling systems in these areas. In this study, a robust monitoring network is introduced that focuses on groundwater recharge across the vertical profile of the karst aquifer, known as the karst critical zone, which includes the atmosphere, vegetation, soil, and both the unsaturated and saturated zones of the aquifer. In the Postojna-Planina karst region in SW Slovenia, we have established 21 monitoring sites both on the surface and underground. The work includes detailed inventories of geology, geomorphology, vegetation and soil properties. Using specially developed equipment, we continuously monitor various parameters such as open-field precipitation, throughfall, air and soil temperature, soil moisture as well as the flow and levels of cave seepage, sinking streams, underground rivers, springs, and water properties such as temperature and electrical conductivity. The study provides an assessment of the strengths, weaknesses and opportunities of the monitoring network, offers new insights into karst hydrology and represents a globally unique approach to the important area of research.

EROSION CONTROL: TILLAGE CHOICES FOR SUSTAINABLE AGRICULTURE

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KEYWORDS:
Agroforestry, Intercropping, Runoff, Soil Erosion

With rising global concern about soil degradation, this study investigates the impact of different tillage practices on runoff and sediment loss in an agroforest setting in N-W Croatia, aiming to identify sustainable management strategies for mitigating erosion and preserving soil quality. Soil degradation is a significant environmental challenge, threatening agricultural productivity and ecosystem services. In particular, soil erosion, often exacerbated by unsustainable agricultural practices, leads to a loss of topsoil, reduced fertility, and impaired water quality. The experiment was conducted at the Marija Magdalena site with a slope of 22.5°, characterized by Vertisols and a plum orchard with maize grown in the interrows. A total rainfall of 650 mm m^{-2} occurred during the experiment, providing sufficient conditions to assess the impact of tillage practices on runoff and sediment loss. Two tillage treatments were implemented: conventional tillage, which involved ploughing to a depth of 25 cm, and conservation tillage, which utilized a non-inverting cultivator to a depth of 15 cm. Runoff and sediment loss were measured in situ after significant erosive rainfall events by using fenced plots of 2x10 m with a collector. The measurements were taken following periods of intense rainfall to assess the effectiveness of each tillage practice in mitigating runoff and soil loss. A two-way ANOVA analysis revealed a significant difference ($p < 0.05$) in both runoff and sediment loss between the treatments, with significantly higher values observed under conventional tillage compared to reduced tillage across all measurement periods. For example, conventional tillage resulted in 94.0% higher runoff and a corresponding increase in sediment loss compared to conservation tillage in the first measurement period. This highlights the significant impact of tillage practices on soil erosion and runoff. Sediment concentration and sediment loss were highly correlated with runoff, indicating a strong link between these factors. The presence of a high correlation emphasizes the importance of reducing runoff to minimize sediment transport and subsequent soil degradation. This study highlights the significant role of tillage practices in mitigating runoff and sediment loss, and promoting soil conservation in agroforest settings. Further research will investigate the long-term effects of these tillage practices on soil quality, crop yields, and the optimization of management strategies for sustainable agriculture in similar agro-ecosystems.

BIODIVERSITY ASSESSMENT USING THE BIODIVERSITY INDICATOR AND REPORTING SYSTEM (BIRS) METHODOLOGY AT HOLCIM QUARRIES IN CROATIA

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KEYWORDS:
biodiversity assessments, BIRS, ecosystem evaluation, environmental survey, quarries

Although many scientists in biology field have been concerned about global biodiversity loss for decades, just very recently, biodiversity loss has been recognized as one of the major threats to the humanity by important institutions (UN 2020, WEF 2023). Land use change, resource overexploitation, invasive species, climate change and pollution are announced to be main drivers for biodiversity loss (Millennium Ecosystem Assessment, 2005). EU Biodiversity Strategy 2030 (EC 2020ª) highlights the need to integrate biodiversity consideration into public and business decision-making at all level, and Convention on Biological Diversity (CBD, 2022) stresses the need to take measures encourage business to regulary monitor, assess, and transparently disclose their risk, dependences and impacts on biodiversity commits to the development of methods along their value chain. Therefore, scientifically robust model and indicators are developed to capture impacts of biodiversity from a value-chain perspective, enabling business to identify drivers biodiversity loss, and also to monitor evolution of impacts and to design mitigation strategies.

10 years ago IUCN created the Biodiversity Indicator and Reporting System (BIRS) in other to help companies in cement and aggregates sector to monitor biodiversity at their extractive operations and to report on biodiversity attributes at the company level (IUCN, 2014). BIRS is highly adopted to measure relative progress (succession) or degradation process in certain time sequence and does not provide absolute value of biodiversity.

As an external expert team, CFRI researchers were involved in the first Biodiversity survey in 2019 on 4 locations of Holcim localities and again in 2024 on 7 locations. The BIRS method was used to assess the overall biodiversity suitability of a defined site consisting of one or more different habitat types. Different habitat types were determined, each representing different natural stages or impacts of human activities. The assessment results show that the areas without quarry works are mainly habitats with natural vegetation, such as forests, shrublands, and woodlands, which are typical for the climate in which they are present. It is to be expected that their removal will significantly change the overall biodiversity. Also, the areas that have been outside the quarry for a certain period of time show a rehabilitation character that is supported by the human factor, such as the planting of pioneer tree species.

IDENTIFICATION OF LIVING CONDITIONS OF SUMMER TRUFFLE (*Tuber aestivum*) IN NATURAL PRODUCTIVE SITES OF ISTRIAN PENINSULA

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KEYWORDS: *DNA metabarcoding, ectomycorrhizosphere, mycorrhiza helper bacteria, quantitative real-time polymerase chain reaction, summer truffle*

The ecological, social and economic value of ectomycorrhizal fungi, such as truffles (*Tuber* spp.) is well known. The inoculation of tree species with such targeted mycorrhizal fungi and rhizobacteria can improve the physiology and morphology of the seedlings as well as produce edible carpophores. The aim of this research is to identify the suitable habitat conditions of summer truffle (*Tuber aestivum* (Wulfen) Spreng.) in natural productive sites of Northern Adriatic area in order to achieve better understanding of natural processes that occur in ectomycorrhizosphere zones and to be able to replicate those conditions during the seedling inoculation and orchard establishment. Istrian peninsula in Croatia was selected as pilot area, where 65 productive plots were identified. In each productive plot, soil samples were taken underneath the ascocarp and outside the productive zone, resulting in total of 65 soil sample pairs, or 130 individual samples. Sampling was carried out in Turkey oak (*Quercus cerris* L.) and pubescent oak (*Quercus pubescens* Willd.) dominated ecosystems, that are the most common hosts of summer truffles. During the sampling period, no fruiting bodies were found on plots were Aleppo pine and holm oak are predominant species. For each soil sample pair, the location was recorded and described. Soil physico-chemical analysis, ascocarp PCR test, mycelial qPCR tests and DNA metabarcoding for fungal and bacterial communities were performed. The difference in soil properties and fungal and bacterial communities between each soil sample pair will be further used to describe the limiting conditions for fruiting body development of summer truffles.

INOCULATING VARIOUS FOREST SEEDLINGS WITH BLACK TRUFFLES

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KEYWORDS:
Inoculation, Quercus, S eedlings, Truffles, Tuber

Mycorrhiza is a mutualistic symbiosis between plants and fungi in which the fungi help the plant absorb nutrients, especially poorly soluble elements such as phosphorus. In return, the plant hands over organic carbon fixed by photosynthesis to the fungus. Truffles (*Tuber* spp.) are fungi that form hypogeous fruiting bodies and establish an ectomycorrhizal relationship with plant species, without which they cannot complete their life cycle. Truffles are intensively cultivated due to their gastronomic value and decline in natural production.

CFRI is conducting a project to inoculate seedlings of economically important forest tree species with black truffles (T. *melanosporum* - black and T. *aestivum* - summer truffles). The research aims to find the optimal method of inoculation that would provide quality and healthy seedlings. Plants with mycorrhiza have more significant growth in thickness and height, have a larger leaf area, are more resistant to leaf and root pathogens, use available resources in the soil more efficiently, and better tolerate shock transplants, salt and drought. Inoculated seedlings can be used for afforestation, rehabilitation of degraded habitats and habitats poor in nutrients (e.g., areas damaged by fire), and to ensure the continuation of natural succession.

Seedling species included in the inoculation research are mainly species of the genus Quercus (*Q. robur, Q. petraea, Q. pubescens, Q. cerris, Q. ilex*), followed by *Corylus avellana, Pinus halepensis, Carpinus betulus,* and *Ostrya carpinifolia*, to cover as wide a range of temperate forest ecosystems. The inoculation experiment was set up for all plant species equally (same amount of truffle spores and nutrients), and all seedlings were grown in the same semi-controlled conditions. According to the Fischer and Colinas (2014) method based on counting colonized root tips, inoculated seedlings were evaluated more than a year after inoculation. The results so far confirm the successful invention of the inoculation method.

Further research would include transplanting the seedlings into the field, where the development of inoculated seedlings and mycelia in the soil would continue to be monitored under outdoor conditions.

PHENOTYPIC VARIATION IN LEAF AND FRUIT TRAITS IN NATURAL POPULATIONS OF QUERCUS PETRAEA ((MATT.) LIEBL.) IN BOSNIA AND HERZEGOVINA

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KEYWORDS:
fruit traits,
leaf traits,
natural populations,
sessile oak,
variation

Quercus petraea (Matt.) Liebl., (sessile oak) is a common broadleaved tree species in Europe, found from Scandinavia to the Iberian Peninsula. In Bosnia and Herzegovina, it occurs in about 15% of all forests, and has a significant economic and ecologic role. This research aims to determince intrapopulation and interpopulation variation of leaf and fruit traits of sessile oak in natural populations in Bosnia and Herzegovina.

23 traits of leaves and fruits (twelve for leaves and ten for fruits) were analyzed on 64 trees from seven natural populations of sessile oak.

The results showed that the coefficients of variation for all measured traits ranged from 12,2% for the cupule width to 36,6% for the ratio of petiole lengdth and leaf width. Analysis of variance (ANOVA) revealed the existence of phenotypic variation among and within populations. Variation among populations was on average 68,25% and higher than within populations (average 30,34%). Cluster analysis showed the separation of populations into four main clusters, separating Bihać-Gata population to the first, Sanski Most population to the second, populations Kreševo Jelaške, Bosanska Krupa and Ključ to the third and populations Tešanj and Bužim Baštra to the fourth cluster.

The research results can be used for the diversity conservation and resource management of the species in the future.

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NEW INSIGHTS INTO GENETIC DIVERSITY OF EUROPEAN WILD PEAR (*Pyrus pyraster* (L.) Burgsd.) AND ALMOND-LEAVED PEAR (*P. spinosa* Forssk.) IN CROATIA: IMPLICATIONS FOR THEIR CONSERVATION AND PROTECTION

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KEYWORDS:
l fruit traits, leaf traits, natural populations, sessile oak, variation

The genus *Pyrus* L. belongs to the Rosaceae family and comprises over 80 described species and numerous cultivars which are of great ecological and economic value. In southern Europe, the key species include *Pyrus pyraster* (L.) Burgsd. and *P. spinosa Forssk*., both of which are pollinated by insects and dispersed by animals. Within this taxonomically complex genus, interspecific hybridisation has frequently been reported. In this study, 21 wild populations of *P. pyraster* and 22 of *P. spinosa* as well as 24 cultivars of *P. communis* L. were analysed. The aim was to assess the presence of hybridisation and the genetic diversity and structure within these species. For this purpose, nine simple sequence repeat (SSR) primers were used. In general, a higher genetic diversity was found in *P. pyraster* compared to P. spinosa. A significant historical bottleneck was observed in the southern *P. pyraster* populations. Significant genetic differences were found both between and within the populations studied. The introgression of cultivated pears was particularly pronounced in three Mediterranean populations of P. pyraster (45 hybrid individuals), whereas it was rare in *P. spinosa* with only 10 individuals. In addition, 14 hybrids between the two wild species were found in areas where their ecological niches overlap. Mantel tests showed that genetic distances correlated with geographical distances (IBD) but not with environmental distances (IBE) in both wild species. This study provides valuable insights into the genetic variability of these species, increasing their potential utility for sustainable forest management and breeding programmes. Furthermore, this study has raised awareness of the vulnerability of these wild species to natural hybridisation with cultivated pears. This can have a wide range of evolutionary consequences in natural populations, including the increased risk of their extinction, emphasising the need for better and faster measures to protect and conserve these species.

CLIMATIC VARIATIONS IN THE EU-MEDITERRANEAN AREA IN CROATIA

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KEYWORDS:
climate, climate variations, drought, eu-mediterranean

Climatic conditions in the eu-mediterranean area correspond to holm oak, which is the main type of forest tree in this vegetation zone. However, climate elements and indices are not constants but change over time. The type of climate change as well as its intensity depends on the length of the time period. Climatic variations refer to changes related to shorter periods of time. The trends of climate elements and drought indices were analyzed for seven meteorological stations in the eu-mediterranean vegetation zone for the time period 1981 - 2023. The average values of climate elements and drought of the time period 2011 - 2023 were compared with the reference series 1981 - 2010. Variations in mean annual air temperature (°C) and annual precipitation (mm) were analyzed. The aridity of the area was analyzed by length of the dry season. The month is dry if the monthly amount of precipitation is less than twice the average monthly air temperature, the rain anomaly index (RAI) and the aridity index, which is the ratio of annual precipitation (P) to potential evapotranspiration (PET). Potential evapotranspiration and soil water balance were calculated according to Thornthwaite's method. The trends of climate elements and drought indices were analyzed by the Mann-Kendall trend test. Average values of climate element and drought index were tested by Student's T-test or U-test. Mean annual air temperatures and potential evapotranspiration are significantly increasing ($p < 0.001$), while the amount of precipitation, number of dry months, precipitation anomaly index, aridity index did not have a statistically significant trend of change ($p > 0.05$). The increase in mean annual air temperatures since 2011 compared to the reference series was more pronounced on the islands (Silba + 1.23 °C), while the increase in potential evapotranspiration was more pronounced on the coast, Split + 63 mm. Changes in the amount of precipitation, the number of dry months, the precipitation anomaly index and the aridity index since 2011 were not significant compared to the reference series. In the last ten years, the amount of water deficit in the soil during the dry months has increased significantly compared to the reference series by 134.14 mm. However, the dryness of the vegetation zone according to the number of dry months, precipitation anomaly index and aridity index did not increase. We can conclude that the ecological niche of the holm oak is not threatened in the eu-mediterranean area in Croatia.

MAPPING THE LAND USES IN PROTECTED AREAS OF SPAIN USING HIGH-RESOULUTION SATELITE IMAGES AND RANDOM FOREST MODEL (A CASE STUDY IN ONS ISLAND)

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KEYWORDS: *Forest, Invasive plant species, Machine learning model, Planet Scope satellite image, Protective management*

The protected areas are valuable ecosystems which have many environmental and ecological values. One of the most important protected areas in Spain is Ons Island. This area is a biodiversity hotspot in northwestern Spain which provides valuable habitats for many endemic species. Unfortunately, the natural resources of this Island have been destructed by many factors in recent years. One of the destructive factors of native plant species is establishment of invasive plant species like Acacia Melanoxylon in Ons Island which threatens habitat of the main native tree species (*Pinus Pinaster*) in this Island. The first step to know about distribution of *Acacia Melanoxylon* in Ons Island is mapping land uses by new high resolution satellite images and efficient models. This mapping enables us to focus on forest area to identify *Acacia Melanoxylon* in the Island. This research was performed to map the natural covers (mainly forest and rangeland) and human-made land uses in Ons Island using Planet Scope satellite images and random forest model. For this purpose, composite Planet Scope satellite images of the study area (imagery date: June of 2024) were ordered and downloaded from Planet website. Then, training areas for each land use (forest, rangeland, bare soil, stone, residential area, and cropland) were selected on Google Earth satellite images. For this purpose, enough and scattered training areas were selected for each land use in Ons Island. Then, supervised classification of satellite images was done using random forest method because of its high efficiency for classifying the pixels in heterogenous areas. Finally, the newest land use map of study area was obtained in 3m spatial resolution for 2024. Accuracy assessment of land use map was done by some square plots on Google Earth images (different from training areas) and accuracy indices. Results showed that rangeland is the largest land use in Ons Island. Results of validation of land use map showed that Planet Scope satellite images and random forest model have high efficiency (OA: 94%) in land use mapping in the study area. The forest map extracted from land use map in this research is a valuable map to identify *Acacia Melanoxylon* inside forest area in Ons Island. In addition, human-made land uses obtained from land use map in this study can be used for investigating the relationships between location of human activities and distribution of *Acacia Melanoxylon* which will be performed in our future research following this study.

CAUSAL AI MODELLING AND PREDICTION OF FOREST FIRES IN MEDITERRAN

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KEYWORDS:
climate, forest fire, Bayes, structural causal modelling

Applied are methodologies of artificial intelligence AI and causality analysis for modelling and prediction of forest fires in Mediterrian countries. The models are based on climatology data, FWI Canadian Forest Service indices, and temporal and local geographical positions. The data are based on open source provided by EFFIS (European Forest Fire Information Systems). Presented are modelling results based on the data from Croatia, Portugal and Algeria. Causal analysis is based on GML Bayes linear predictions and nonparametric kernel based RF random forest and SVM support vector machines. The causal relations are presented as DAG directed acyclic graphs enabling de-confounding by d-separation principle. Application of XGB extreme gradient boosting models on untrained (new data) yielded 60% accuracy in prediction of forest fire occurrence and error of 15 ha in prediction of burned area. As the main cause factors are inferred with relative importance: temperature 16%, relative humidity 14%, and 12% for surface dryness by Duff moisture code (DMC). The causal dependences are evaluated by adjusted DAG and Bayes neural networks. Nonlinear relations are presented as partial dependency plots. Especially in view of drone light detection and ranging (LiDAR) sensor technologies, discussed is potential application of the causal AI for monitoring and management of forest fires.

VALIDATION OF THE BIOME-BGCMUSO MODEL FOR ESTIMATING SOIL ORGANIC CARBON CHANGES IN OAK CHRONOSEQUENCE IN CROATIA

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KEYWORDS:
Carbon stock change, Chronosequence resampling, Process-based model, Soil organic matter

Soil organic matter is the largest carbon pool in forest ecosystems and its dynamics play an important role in nutrient cycling and forest productivity. Carbon in mineral soils which is of organic origin is referred to as soil organic carbon (SOC). Due to the ongoing climate change, alterations in SOC are expected, therefore monitoring and understanding this carbon pool is important. Detecting changes in the SOC is challenging due to its high spatial variability and slow dynamics of its loss and accumulation. Thus, soil inventories require high sampling density, which poses a significant cost. An alternative is to use the modelling approach. Models, however, need to be calibrated and validated by verifying model results with measurements, for which wide-scale and/or long-term field measurements of ecosystem variables are desired. This research aims to investigate the applicability of the process-based model Biome-BGCMuSo for estimating changes in SOC down to 30 cm soil depth (SOC_{30}) in the oak chronosequence in Croatia. The model Biome-BGCMuSo (version 6.2) was validated for estimating short-term and long-term SOC_{30} changes using measured SOC_{30} in six pedunculate oak stands from the chronosequence experiment. The soil was sampled at permanent plots for three consecutive years (2012, 2017, 2022). Trends in the measured and modelled SOC_{30} were investigated for a ten-year period (2012-2022) and throughout the rotation period. Both measured and modelled SOC_{30} were found to be stable during the investigated period from 2012 to 2022. Nevertheless, the divergent trends observed in measured and modelled SOC_{30} (negative for measured and positive for modelled SOC_{30}) suggest more thorough research including longer time series is required. When looking at the SOC_{30} changes with stand age, no age trend in measured or modelled SOC_{30} was found when analysing each sampling year separately. However, using a repeated chronosequence approach by combining data from all three sampling years revealed a significant increasing trend in measured SOC_{30} with the stand age, while modelled SOC_{30} did not show a trend with the stand age. Acknowledging the general assumption that under the shelterwood regeneration system (commonly used in oak forests) SOC is stable with time, the observed increasing trend of measured SOC_{30} with stand age should be interpreted carefully. On the other hand, modelled SOC_{30} increased with the increasing soil clay content and decreased with the increasing soil sand content, indicating that the soil texture is a stronger driver of modelled SOC_{30} than the stand age.

ACCURACY ASSESSMENT OF PERSONAL LASER SCANNING ESTIMATES OF THE MAIN TREE ATTRIBUTES IN VEGETATION AND NON-VEGETATION PERIOD IN MIXED COMMON BEECH FOREST

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hand-held personal laser scanning,
diameter at breast height,
tree height,
forest inventory

In the last decades, technological advancements in the laser scanning industry have given rise to the development of lightweight and mobile laser scanning instruments. With the new versions of the instruments being released from companies such as FARO and GeoSLAM, a modern way of conducting forest inventories has opened up. The estimation of the main three attributes using hand-held personal laser scanning (PLS_{HH}) instruments has been raised as a research topic each continuous year. The goal of this study was to compare the accuracy of diameter at breast height (dbh) and tree height (h) estimates using PLSHH in a middle-aged common beech (*Fagus sylvatica* L.) forest in Central Croatia during both vegetation and non-vegetation periods. A PLS_{HH} survey of three circular sample plots with radii of 12.62 m was conducted using the GeoSLAM Horizon instrument and a pre-planned scanning scheme that provided the optimal coverage of each sample plot. In addition to the PLS_{HH} survey, field and TLS surveys were conducted on the same plots using a diameter tape and a terrestrial laser scanner (TLS) Faro Focus M70, respectively. Field measurements and TLS estimations were used as reference data for dbh and h estimates, respectively. TLS and PLS_{HH} data were then processed in the LiDAR360 software from which the dbh and h estimations were extracted. The estimations, from both vegetation and non-vegetation periods, were compared with the reference data. The non-vegetation PLS_{HH} dataset provided more accurate estimations, especially for h. In conclusion, the vegetation is an obstacle in the way of the PLSHH instrument for it to provide accurate main tree attribute estimations.

THE DIFFERENT TIMING OF EXPOSURE TO DROUGHT STRESS DIFFERENTIALLY AFFECTS GROWTH IN PEDUNCULATE OAK

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drought stress, height growth, Quercus robur L.

Forest trees are increasingly facing periods of drought, and according to current research, drought stress in different species of forest trees results in reduced height growth, delayed or advanced bud burst in spring, and leaf senescence in autumn. However, the main question of this study is how the timing of drought stress induction affects the height growth in pedunculate oak (*Quercus robur* L.).

120 one-year-old pedunculate oak seedlings, were divided into five equal groups. Four groups were subjected to drought stress, each at different times of the growing season, from mid-April to the end of July 2022. The fifth group served as the control. Each seedling was exposed to drought until visible symptoms of drought stress appeared, and when the seedling's mass with its container dropped below 50% of its initial mass. At that point, the drought treatment was terminated, and plants were rehydrated and regularly irrigated until the end of the growing season. Control seedlings were regularly irrigated. Drought stress was induced again in 2023 with the same dynamics.

In the first year of the experiment, there was no statistically significant difference in height growth between any group and the control; however, the first group recorded higher average height growth compared to the control. In the second year of the experiment, the second, third, and fourth groups showed significantly reduced height growth compared to the control. Considering the overall height growth over the two years of the experiment, the second, third, and fourth groups showed significantly reduced height growth.

This research indicates variations in drought effects on pedunculate oak, depending on the timing of the growing season when the stress is induced.

INVASION DYNAMICS OF HIMALAYAN BALSAM ALONG THE BREGANA RIVER

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KEYWORDS:
biodiversity, invasive alien plants, Impatiens glandulifera, LIFE OrnamentalIAS, riparian habitats

Himalayan balsam (*Impatiens glandulifera* Royle), native to the western Himalayas, has become naturalized in northern and central Europe, temperate North America, and New Zealand. In Europe, it is one of the most widespread invasive alien species (IAS) and is included on the list of IAS of Union concern. Its rapid spread, particularly in riparian habitats, poses significant conservation challenges. The dominance of *I. glandulifera* along riverbanks interferes with water side management, as its vigorous growth displaces native vegetation. As the tallest annual herb in Europe, it is highly competitive, often outcompeting native plant species and disrupting local ecosystems. In Zagreb County, the presence of *I. glandulifera* was first observed in 2020 along the Bregana River, initially confined to a small area. However, in recent years, its spread has intensified, raising concerns about its potential ecological impact. This study presents the first monitoring activities for *I. glandulifera* in the Zagreb County, utilizing the QField application for data collection. The initial monitoring conducted in 2022 identified the species covering approximately 260 m^2 along the Bregana River. By 2024, a subsequent survey of the same area revealed a dramatic increase in coverage, with *I. glandulifera* now occupying 3,500 m^2. The findings highlight the species' remarkable ability to spread rapidly, particularly in riparian environments. Over just two years, *I. glandulifera* has significantly expanded its range, demonstrating its high invasive potential. Given this rapid expansion, it is clear that I. *glandulifera* could pose a serious threat to biodiversity and nature conservation efforts in the future if left unmanaged. This observations underscores the urgent need for continued monitoring and implementation of eradication strategies to mitigate the spread of this invasive species and protect native ecosystems from further degradation. Through the LIFE OrnamentalIAS project, which addresses the issue of invasive ornamental species, we aim to investigate and apply effective eradication measures for I. *glandulifera*.

ASSESSMENT OF CLIMATE EXTREMES IN HIMACHAL PRADESH: ANALYSIS OF KEY CLIMATE INDICES AND THEIR IMPLICATIONS FOR REGIONAL VULNERABILITY

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KEYWORDS:
Climate Change, climate Indices, Extreme Precipitation, Himachal Pradesh, Temperature Trends

The present study investigates the changing climate patterns in Himachal Pradesh, India, using key climate indices such as Dry Days, Wet Days, Precipitation at the 95th and 99th Percentiles, Frost Days, Tropical Days, Maximum Temperature, and Minimum Temperature. These indices are critical for understanding the shifts in weather extremes in this mountainous region, which is highly vulnerable to climate change. Using historical weather data, trends in dry and wet days show increasing variability, with a significant rise in heavy rainfall events, as indicated by the 95th and 99th percentile precipitation indices. Concurrently, an alarming increase in Tropical Days and a reduction in Frost Days suggest a warming trend in the region, while changes in maximum and minimum temperatures further underscore this warming. The findings point toward increased climatic stress, especially for agriculture, water availability, and natural ecosystems, stressing the need for proactive adaptation and mitigation strategies in Himachal Pradesh.

INVESTIGATION OF THE PRESENCE OF OTHER HARMFUL ORGANISMS ON SAMPLES COLLECTED FOR THE PURPOSE OF SPECIAL SURVEILLANCE OF THE QUARANTINE HARMFUL ORGANISM -GEOSMITHIA MORBIDA

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quarantine harmful organism, special surveillance, saprotroph fungi, parasites fungi, Juglans spp.

The fungus Geosmithia morbida is responsible for the mortality of Juglans spp. The vector for the fungus is the insect Pityophthorus juglandis, also known as the walnut twig beetle. The fungus and the vector are included on the EPPO Alert list. In 2013, researchers identified the disease in the Veneto region of Italy, targeting black walnut trees. In considering the presence of walnut stands and clonal archives in Croatia, specialized visual examinations of walnut trees have been conducted as part of the European Program of Special Surveillance of Harmful Plant Organisms since 2015. The objective is to ascertain the existence of G. morbida and the vector P. juglandis, evaluate their distribution and impact, and implement control and eradication measures if deemed essential. The specialized surveillance program encompasses regions adjacent to the borders with Italy, Slovenia, Hungary, and Serbia. Program activities are conducted in the counties of Istria, Koprivnica-Križevci, Međimurje, Varaždin, Vukovar-Srijem, and Zagreb. This study aims to detect the presence of the fungus G. morbida and other harmful fungal organisms in wood samples of Juglans spp. Trees in forest stands, cultures, and clonal seed orchards were examined, and samples of wood exhibiting damage signs were collected. The plant material was analyzed macroscopically and microscopically in the laboratory, and the diseased sections of wood and fungal components were isolated. The collected samples were prepared for DNA analysis. The fungi species were identified by DNA barcoding utilizing the ITS region and electronic genetic databases (NCBI GenBank, MycoBank, and the Barcode of Life Data Systems (BOLD)). The quarantine fungus G. morbida was absent in the samples analyzed. Other fungi identified in wood samples belong to the phylum Ascomycota, class Dothideomycetes (orders Pleosporales, Capnodiales, Cladosporiales, Botryosphaeriales), class Sordariomycetes (orders Xylariales, Hypocreales, Microascales, Togniniales, Amphisphaeriales, Diaporthales), class Leotiomycetes (order Helotiales), class Eurotiomycetes (order Chaetothyriales); the phylum Basidiomycota, class Agaricomycetes (orders Agaricales, Cantharellales, Polyporales, Hymenochaetales, Russulales). Macrofungi and microfungi from the categories of parasites and saprotrophs were identified. The fungi induce necrosis (e.g., Cadophora novi-eboraci, Fusarium sp., Alternaria alternata), branch and trunk cancer (e.g., Eutypa sp., Diplodia serata, Diaporte eres), and wood rot (e.g., Schizophyllum commune, Plebia radiata, Exidia glandulosa, Daedaleopsis confragosa), resulting in branch drying and tree mortality.

EFFECT OF CLIMATE CHANGE ON INCREASING ESTABLISHMENT OF INVASIVE PLANT SPECIES: AN IMPORTANT CHALLENGE FOR BIODIVERSITY OF NATIVE SPECIES IN CHANGING WORLD

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KEYWORDS: *Temperature, precipitation, invasive plant s pecies (IPS), biodiversity, climatic scenario*

Climate change has created many challenges in natural ecosystems around the world. This phenomenon can change the structure of the forests, destroy the biodiversity, alter the distribution and composition of the plant species, make extinct the endemic species, and increase some non-native species in different ecosystems. One of the most important effects of climate change on ecosystems is increasing establishment of invasive plant species (IPS) in these areas. Investigation of the impacts of climate change on this phenomenon is essential to control it in the changing world. This study has been performed to investigate the effects of climate change on distribution of IPS, introducing the most important climatic variables and most practical method for performing it, and innovating in the role of climatic scenarios on prediction of future distribution of IPS in different ecosystems. Results of reviewing papers in this study showed that climate change has many direct and indirect effects on increasing establishment of IPS in different ecosystems. However, direct effects of climate change on it are stronger than its indirect impacts. Among all disturbances derived from climate change, fire has been one of the most important disturbances which has increased the establishment of IPS in natural ecosystems. In addition, based on the findings of most studies, temperature and precipitation have been the most important climatic variables in increasing establishment of IPS in the ecosystems. Although prevention of climate change is inevitable, reduction of some effects of this phenomenon on ecosystems is possible using new applicable methods and modern technologies. The practical method presented in this study is a simple and applicable method to detect the effect of climate change on increasing establishment of IPS in natural areas. It will be helpful for estimating the current distribution of IPS in the ecosystems based on climatic variables. In addition, climatic scenarios are very effective tools for prediction of future distribution of IPS in different ecosystems which are helpful for protective management of natural areas against increasing establishment of IPS in the changing world.

HYDRO-CLIMATE EXTREMES IN THE HIMALAYAN WATERSHED: A CASE OF THE GANDAK WATERSHED

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KEYWORDS:
Extreme climate indices, CMIP6, climate change, wet days, dry days

Climate change variability and intensification of extreme events are impacting both human and ecological health worldwide. This study focuses on analyzing hydro-climate extremes in the snow-fed Gandak wastershed, a region with potential for water infrastructure development located in the central Himalayas, spanning parts of Nepal and India.Future climate projections for the near-term (2020-2050) and far term (2060-2090) under socio-economic pathway scenarios of ssp245 and ssp585 were developed using ensemble model of CMIP6, bias corrected using machine learning technique. Historical trend (1984-2014) and projected future trends for selected climate extremes were assessed using XclimeDex for climate indices and the indicators of hydrological alteration tool for hydrological extremes.

The findings reveal that past trends in precipitation extremes, such as heavy and very heavy precipitation days and maximum 1-day precipitation, are delcining, while temperature-related extremes show both upward and downward trends. This suggests a shift towards drier and hotter conditions during historical period. Future projections indicate and increase in temperature extremes, like hot nights and warm days, across both scenarios, while some precipitation extremes. Such as consecutive dry and wet days and maximum 5-day precipitation, show a declining trend. These results point to a continued trend of hotter and wetter conditions in Gndak watershed, with potential consequences for future water availability, water allocation conflicts, river health.

FERTILIZATION ENHANCES DROUGHT RESILIENCE AND RECOVERY OF PHOTOSYNTHESIS IN EUROPEAN BEECH SAPLINGS

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KEYWORDS:
drought, fertilization, nitrogen, photosynthesis, recovery

Climate change is expected to increase the frequency and intensity of short-term drought periods globally, posing significant threats to forest ecosystems. European beech (Fagus sylvatica) is a dominant tree species in temperate forests, known for its ecological and economic importance. However, beech seedlings are particularly vulnerable to drought stress, which can negatively impact their growth, survival, and establishment. Understanding the ability of beech saplings to recover from drought stress is crucial for assessing their long-term resilience and adaptability. This study aims to investigate the level of drought stress by measuring predawn leaf water potential and the response of photosynthesis during short intense summer drought, as well as the recovery ability of fertilized and unfertilized European beech saplings under controlled greenhouse conditions. Four combinations of watering and fertilization were applied: WH (regular watering, fertilization), WL (regular watering, no fertilization), DH (drought, fertilization) and DL (drought, no fertilization). Photosynthetic activity was monitored throughout the vegetation season by measuring the photosynthesis rate (A) and chlorophyll fluorescence (PItot, Fv/Fm). Foliar samples were collected for analysis of nitrogen and chlorophyll (Chla+b) concentrations in pre-drought, drought, and post-drought phase. Fertilization increased the concentrations of foliar nitrogen in leaves, even under conditions of drought stress. The higher foliar concentration of nitrogen improved photosynthetic activity in all treatments. The chlorophyll fluorescence parameter PItot better reflected changes in photosynthetic efficiency related to fertilization compared to Fv/Fm. Fertilization mitigated the negative effects of drought on PItot, helping to maintain photosynthetic efficiency in beech seedlings, likely due to the higher concentration of nitrogen in leaves. Furthermore, fertilization significantly increased the Chla+b concentrations in leaves, positively affecting photosynthetic productivity, particularly in the post-drought period. Fertilized drought-exposed saplings had higher A during drought and in the post drought phase and also exhibited faster recovery after re-watering, suggesting that beech has a mechanism for compensating lost photosynthetic activity during drought when water conditions improve. Overall, our observations suggest that adequate fertilization can mitigate the negative effects of drought, improving the resilience and recovery of the photosynthetic response of beech saplings.

EARLY SELECTION OF MOST APPROPRIATE POPLAR AND WILLOW CULTIVARS FOR LANDFILL REMEDIATION USING PLANT PHYSIOLOGY PARAMETERS

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KEYWORDS:
Landfill, clones, net photosynthesis, WUE, transpiration, stomatal conductance, SPAD

The effect of landfills on the environment reflects the dispersion of the contaminants on surrounding soils by the groundwater plume. Such negative effect can be mitigated with the establishment of vegetative buffers surrounding landfills. The "TreeRemEnergy" project funded by the Science Fund of Republic of Serbia – Green program focuses on development of phyto-buffers for landfill phytoremediation with the use of Short Rotation Woody Crops (SRWC) plantations that can be further used for the biomass for energy. One of the goals of the project is to select the most appropriate poplar (Populus sp.) and willow (Salix sp.) clones through phytorecurrent selection that involves testing of various breeding traits. Physiological parameters serve as a significant contribution to the breeding process aimed at early detection of potential candidates. This study involved testing the effect of the landfill soils on the photosynthetic processes of the selected poplar and willow candidates in greenhouse pot trial. For this purpose, measurements of the gas exchange, chlorophyll content and chlorophyll fluorescence were measured on the tested plants. There was significant effect of interaction ClonexSubstrate in intercellular CO2 concentration(ci), stomatal conductance (gs) and transpiration rate (E), suggesting that water regime of the tested clones differed considering tested substrates. Some clones showed more "generalist" behavior (380, 107/65/9, and PE19/66), while "specialist" behavior was recorded in clones PE4/68, S1-8, and 79/64/2. On the other hand, there was no significant effect of the tested substrate on the pigments content measured with SPAD meter. Results of this study allowed us to narrow the group of clones for further trails in field conditions.

EVALUATING THE RELATIONSHIP BETWEEN LAND SURFACE TEMPERATURE AND DIFFERENT LAND INDICES IN SOUTH DELHI USING LANDSAT DATA

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KEYWORDS:
Climate change, NDVI, NDBI, land surface temperature, correlation analysis

In various regions globally, rapid population growth driven by industrialization and urbanization is causing significant challenges. Unplanned urban expansion, particularly in developing countries, is a major environmental issue as it frequently results in the loss of open and green spaces. As urban areas expand, vegetation cover decreases and more impervious surfaces such as buildings, parking lots, and pavements are created. This can cause environmental pollution, water pollution, climate change, greenhouse gas emissions, and disruptions to ecological cycles. This study investigates the relationships between land surface temperature (LST), the Normalized Difference Built-up Index (NDBI), and the Normalized Difference Vegetation Index (NDVI), with a particular focus on the impact of climate change. Utilizing remote sensing data and statistical methods, the research explores how LST interacts with urbanization and vegetation indices across different temporal scales. The results show that LST had a positive linear relationship with NDBI (R2= 0.93). The LST of the city has increased due to rapid urbanization and loss of vegetation cover. NDVI has a negative relationship with LST (R2= 0.70) and NDBI (R2=0.84). Higher LST has low NDVI values and high NDBI values. Lower LST has higher NDVI values and lower NDBI values. We found a strong negative correlation between NDVI and LST and a positive correlation between NDBI and LST. A negative correlation between LST and NDVI suggests that areas with dense vegetation experience lower temperatures, emphasizing the cooling effect of green cover. These results indicate that the increase in population density, urban growth, and infrastructural developments in South Delhi have led to a decrease in greenness. The outcomes of our study will be used to inform regional and urban planning.

DROUGHT IMPACT ON PHOTOSYNTHETIC PIGMENTS IN COMMON BEECH AND SESSILE OAK LEAVES

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KEYWORDS:
carotenoids, chlorophyll, drought stress, Fagus sylvatica, Quercus petraea

Common beech (*Fagus sylvatica* L.) and sessile oak (Quercus petraea (Matt.) Liebl.) represent forest trees that often coexist in the same habitats where they form mixed stands with very high economic, ecological and social value. Even though they occur in the same habitats, the physiological and/or morphological traits of the common beech and the sessile oak are different. Common beech is characterized by more mesophilic traits and is more sensitive to drought, while the sessile oak is characterized by more xerophilic traits and is more tolerant to drought. Under drought conditions, more drought-tolerant species can maintain a higher concentration of photosynthetic pigments than less drought-tolerant species. Therefore, it is hypothetically possible to assume that the drought could have a more negative impact on the concentration of photosynthetic pigments in the leaves of the common beech than in the sessile oak. Accordingly, this research aimed to determine the concentrations of photosynthetic pigments and their ratios in the leaves of the common beech and the sessile oak, during the wet 2022 and the dry 2023 years. A factorial ANOVA was carried out to examine the effect of species (common beech vs. sessile oak), drought (wet 2022 vs. dry 2023 year) and their interaction on the concentrations of chlorophyll *a*, chlorophyll *b*, total chlorophyll and carotenoids, as well as ratios of chlorophyll *a/b* and total chlorophyll/carotenoids. According to the results, the concentrations of chlorophyll a, chlorophyll b, total chlorophyll and the ratio of chlorophyll a/b were significantly influenced only by year. This means that these parameters were similar in both species but significantly lower in the dry year of 2023 compared to the wet year of 2022. Carotenoid concentration was significantly influenced by both species and year, without interaction. This indicates that the concentration of carotenoids was significantly higher in the leaves of common beech compared to sessile oak, and in the leaves of both species, it was significantly higher in the dry year of 2023 compared to the wet year of 2022. The ratio of total chlorophyll/carotenoids was significantly influenced by species, drought, and their interaction. This indicates that the ratio of total chlorophyll/carotenoids was significantly lower in the leaves of common beech compared to sessile oak in the wet year of 2022, while in the dry year of 2023, the ratio was similar for both species.

ENHANCING CLIMATE CHANGE GOVERNANCE IN SERBIA: STRATEGIC AND LEGAL FRAMEWORK IN FORESTRY AND RELATED SECTORS

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KEYWORDS:
climate change, forestry, governance, policy, regulatory framework

Effective climate change governance requires the engagement of different social, economic and political actors to develop harmonised policies and appropriate measures to mitigate and adapt to climate change. The implementation of these measures requires, among other things, a comprehensive strategic and legal framework. Serbia is in the process of harmonising the national strategic and legislative framework with EU requirements and there is also a need to meet international commitments. However, climate change issues are often not fully represented in the national forest policy. The aim of the paper is to identify the opportunities for improving the strategic and legal framework for climate change governance in forestry and related sectors in Serbia. The data was collected through 23 interviews conducted in the period from May to June 2022 in the area of selected forest regions and national parks in Serbia. Decision-makers and experts from the public and civil sectors in forestry and related sectors (nature conservation and environmental protection) as well as representatives of "best practise" examples of climate change governance were interviewed. They were selected according to the following criteria: sector affiliation (public and civil), lower impact in relation to interest in climate change governance, general impression of researchers, and examples of successful collaboration with stakeholders. The perceived problems in the strategic frameworks indicate insufficient cross-sectoral coordination of climate change management policies and measures and insufficient recognition of the role of public, civil and private sector stakeholders at regional and local levels in climate change governance. In accordance with the defined challenges, the implementation of various solutions and activities to improve the strategic and legal framework in forestry and related sectors is proposed. These include, among others, the formation of a cross-sectoral working group to link and harmonize climate change governance policies and measures, assigning a clear role to stakeholders in defining local problems, but also harmonizing their activities by defining the principles of cross-sectoral cooperation in climate change governance at all three levels of governance. In this way, it is possible to create appropriate links between functionally related sectors and to strengthen cross-sectoral cooperation and the active participation of the various actors at regional and local level in climate change governance.

"TO MONITOR, PREVENT AND PROTECT!" – FIVE YEARS OF RODENT MONITORING AT FOREST ADMINISTRATION "VINKOVCI"

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KEYWORDS:
forest protection, monitoring, small rodents, damage

The primary basis for effective pest control lies in the understanding of its population dynamics. Despite their numerous positive ecological roles, small rodents (Murinae:mice; Arvicolinae:voles), are quite known as pests within forest and woodland management in Croatia for impeding forest regeneration, especially during their outbreaks. Since the early 1980s, rodent damage on seeds and saplings of the different tree species (e.g. pedunculate oak and narrow-leafed ash) counted almost 3000 hectare per year in Croatian state forests and the dominant method of controlling rodent populations in those last four decades involved an annual application of nearly 8,5 tons rodenticide on average. These numbers mostly apply for 11 Forest Administrations – Subsidiaries (FAS) situated within continental biogeographic region in Croatia and FAS Vinkovci is usually known for most severe rodent damage and good monitoring practice. The aim of this work was to look into the results of five-year rodent monitoring done at FAS Vinkovci by analysing the data provided by Croatian Forest Research Institute (CFRI) and Croatian forests, limited liability company. From year 2018 to 2022 rodent monitoring at FAS Vinkovci included 10 regional forest offices (RFO) per year and was done on overall 570 trapping locations (min. 78; max. 191; avr. 114/yr.). The average annual number of trapped rodents was 1422 (min. 398; max. 3981, overall 7110); with mice being dominant with overall 6328 (89,0%) individuals compared to 776 (10,9%) voles and six (0,1%) nondetermined individuals. Average annual rodent abundances (RA) in RFOs ranged from 0,0 % to 33,3% with 93% being the highest RA that was recorded in RFO Vrbanja in year 2020. Overall annual average RA for FAS Vinkovci varied from 5,3 % to 20,3% indicating that the rodent population increased during 2018 and 2019, reached its peak in the year 2020 and then crashed in 2021 and 2022. Average share of sedlings with damaged bark varied annualy from 0,2 % to 0,6 % (max. 23,5 % at RFO Vinkovci in 2020) and of those with domaged root from 0,03 % to 0,6 % (max. 11,03 % at RFO Strizivojna in 2020). Damage on forest seeds varied overall from 0,5 % to 0,9 % (max. 15,0 % at RFO Vinkovci in 2020). While monitoring provides very useful information on rodent population dynamics, still it remains highly demanding to fully comprehend their density fluctuations that are the result of highly complex interaction of numerous ecological, but also anthropological factors. Taking into consideration that oak or beech mast triggers rodent population outbreaks, monitoring of tree seed production, should become the next upgrade of the current rodent monitoring method. In time, monitoring rodent populations will surely become even more valuable while it will provide new insights of rodent-borne disease patterns and help decrease the incidence of rodent-borne zoonotic outbreaks.

TESTING THE PERFORMANCE OF THE-STATE-OF THE-ART HAND-HELD PERSONAL LASER SCANNING SYSTEMS FOR TREE HEIGHT ESTIMATIONS IN LOWLAND PEDUNCULATE OAK FORESTS

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KEYWORDS:
close-range remote sensing,
individual tree height,
personal laser scanning,
conventional field measurement,
hypsometer,
forest inventory

Tree height is one of the most important tree attributes in forest inventory, since it is often used to calculate other important variables (e.g. volume, biomass, carbon stock, stand growth and productivity, site index, etc.) at individual tree, plot- or forest stand-level. However, conventional tree height measurements using hypsometers are time-consuming, labour-intensive, and consequently one of the costliest forest inventory measurements. Moreover, conducted research confirmed that conventional tree height measurements can be greatly influenced by many different factors (e.g. forest and tree structure, tree species, tree height, topography, measuring distance, instrument and human errors, etc.) and can cause great estimation errors of other indirectly estimated attributes. Therefore, the main aim of this research to test the performance of two, high-end handheld PLS systems (ZEB Horizon and Faro Orbis) for tree height estimation in a lowland pedunculate oak (*Quercus robur* L.) forest. The PLS data were compared with reference data collected with static terrestrial laser scanning (TLS) data, but also with conventional field data measurements using Vertex hypsometer. According to obtained results, it can be concluded that both PLS instruments provide considerably more accurate tree height estimates than conventional field measurements. Moreover, both PLS estimates were of almost similar accuracy as TLS, while conventional tree heigh measurements provided considerably greater estimation errors that vary depends on tree species, tree height and crown class.

THE INFLUENCE OF CANALS IN A FLOODPLAIN FOREST ECOSYSTEM ON SOIL MOISTURE

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KEYWORDS:
Canals, floodplain forests, pedunculate oak, soil moisture

Forest soil is highly saturated with water due to flood water and a high level of underground water. For a certain period of time, flood water is located on the ground of the forest stand. Small canals are dug in forest stands with the aim of draining excess flood water during the site preparation phase during forest regeneration. The aim of the research was to compare the volumetric soil moisture in the pedunculate oak forest site with canals and the forest site without canals. The dimensions and water levels of maintained canals, unmaintained canals and natural watercourses were compared. Volumetric soil moisture (%) was measured at a depth of 20, 40 and 60 cm in three repetitions from April to July. Water levels in canals and watercourses were measured in April and July at several places along canals and watercourses. Volumetric soil moisture values were compared using the Student's T test, while trends in daily river water levels were analysed using the Mann-Kendall test. The dimensions and water levels of canals and streams were analysed by ANOVA. The daily water levels of the rivers in the research area were in a statistically significant decline ($p < 0.05$). Volumetric soil moisture was significantly lower at all three depths in the forest site with canals compared to the forest stand without canals. The biggest differences were at a depth of 20 and 40 cm and amounted to 10 to 13 % more soil moisture in the site without channels. The smallest difference in soil moisture was at a depth of 60 cm and was 3% higher in the site without canals. Artificially maintained canals had the highest average depths, 41.36 cm, followed by artificial unmaintained canals in the amount of 29.30 cm, and the least natural watercourses in the amount of 13.8 cm. During April, the lowest water levels were in the natural watercourse and unmaintained artificial canals, and the highest in the maintained artificial canal. During the month of July, the highest water level was in the natural watercourse. The water level of canals and streams correlated significantly and positively with their depth ($r=0.61^*$). There was a significant and positive correlation between the water level of the artificial channels ($r=0.49^*$). Considering the trend of decreasing river water levels in the research area it is necessary to consider the depths and purpose of these channels in the future.

USE OF THERMAL IMAGES CAPTURED FROM UAV FOR DETECTING NESTS OF PINE PROCESSIONARY MOTH IN THE LIKA REGION, CROATIA

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KEYWORDS:
PPine Processionary Moth, UAV, Thermal Imaging, Climate Change, Forest Pest Management

The pine processionary moth (Thaumetopea pityocampa Denis & Schiffermüller) has historically been confined to the Mediterranean region due to its warmer climate, which is essential for the species' survival and reproduction. However, recent shifts in climate have facilitated the expansion of this pest into previously unaffected areas, including the Lika region of Croatia. The Lika region, known for its harsh continental climate with cold winters and significant snowfall, was once too inhospitable for the moth. However, increasing temperatures associated with climate change have allowed the moth to survive and thrive in this area, leading to new challenges for forest management.

This study explores the use of Unmanned Aerial Vehicles (UAVs) equipped with thermal imaging sensors to detect nests of the pine processionary moth in the Lika region. The integration of remote sensing technology with deep learning algorithms has proven effective in early detection, which is crucial for managing infestations and mitigating their impact on local pine forests. Our findings suggest that low-cost thermal imaging sensors could possibly identify moth nests, providing a valuable tool for forest managers in managing this expanding pest population.

Session B:

SUISTANABLE PRODUCTION OF FOOD

USE OF BY-PRODUCTS IN THE PRODUCTION OF NEW GENERATION ENCAPSULATED PROBIOTICS

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KEYWORDS:
food industry by-products, freeze-drying, microencapsulation, nanoencapsulations, probiotics

By-products of the food industry are increasingly used for the cultivation and production of nano- and microencapsulated as well as freeze-dried probiotic cells, which we are intensively investigating in our scientific projects funded by the Croatian Science Foundation and EU Funding Programmes. In the production of probiotics, prebiotics, biopharmaceuticals and functional starter cultures, by-products of the dairy industry are most commonly used, such as sweet and sour whey, milk and whey permeate, which have been shown to stimulate the growth of lactic acid bacteria biomass and protect bacterial cells during freeze-drying. By-products such as whey proteins, collagen and chitosan, alginate and carrageenan, as well as gelatin obtained by hydrolysis of collagen, are innovative matrices for the microencapsulation process after cultivation of biomass in order to achieve the highest possible number of live bacteria after drying and to ensure the protective effect of the encapsulation matrix after oral administration and exposure to unfavourable gastrointestinal tract conditions (GIT). These protective matrices form semi-permeable microcapsules that allow the unhindered exchange of nutrients and metabolites necessary for probiotic activity. The measurement of zeta potential confirmed the efficient "layer-by-layer" nano-encapsulation of the probiotic cells, which enables their better survival under simulated GIT conditions and during storage. New sources of fiber, such as acacia, citrus and pea fibers, by-products of fruit and vegetable processing, are being intensively researched as prebiotics to create new functional products such as foods for special medical needs. These innovative prebiotics showed functional effects on the composition of the intestinal microbiota in vitro and in vivo, which were determined in experimental mice. The use of by-products, both in the cultivation, encapsulation and drying of functional starter and probiotic cultures and as innovative prebiotic substrates, can contribute to the realization of a circular economy in the food industry.

MICRO-FORMULATION AS A TOOL TO ENHANCE THE PERFORMANCE OF ASCORBIC ACID AS A FOOD PRESERVATIVE

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KEYWORDS: *Ascorbic Acid, Food spoilage bacteria, Food preservative, Microformulation*

Ascorbic acid (AA), also known as vitamin C, is a food additive (E300) and widely used as a preservative and antioxidant in several food matrices without considerably modifying organoleptic properties. However, AA is very unstable when in contact with oxygen and aqueous solutions and easily decomposes into biologically inactive compounds. To overcome this problem, AA microparticles were formulated using conventional methods such as spray drying and more sophisticated techniques like PGSS® (particles from gas-saturated solutions). Food-grade carriers were used to produce the microparticles: a mixture of pea protein (PP) and maltodextrin (M) for spray drying and glycerol monostearate (GSM) for PGSS®. Both formulations were evaluated and compared to unformulated AA by monitoring antioxidant capacity and release profile at different conditions. Moreover, the antibacterial activity of these formulations was tested against taint-producing Alicyclobacillus spp. that have been correlated with spoilage events in food industries. A design of experiments was made to optimize spray drying and PGSS® processes. Parameters were evaluated to optimize process yield (PY), encapsulation efficiency (EE) and antioxidant capacity (AC). Spray drying particles with optimized responses exhibited a feed concentration of 15 mg/mL and a mass ratio of AA:(PP+M) of 1:4. Optimal PGSS® particles were produced at 150 bar and a mass ratio of AA:GMS of 1:10. Both techniques presented similar PY (~58%). However, spray drying particles presented greater EE (69.83% vs 46.52%) and loading (34.13% vs 8.04%) and AC (2.50 vs 0.14 µMol TE/mgparticles) when compared to PGSS® particles. Particle stability was studied through AA release (%) in aqueous media at pH 7 and 4 and at different temperatures (4°C, 22°C and 37°C). Overall, spray-drying particles exhibited higher AA release in distilled water at all temperatures in comparison with PGSS® particles. However, at pH 4 and 37°C PGSS® particles presented higher AA release. Moreover, the antioxidant capacity of the supernatant generated by the release of the AA was evaluated. Throughout 1 month period, a gradual decrease of the AC could be observed, with independence of pH and temperature conditions. Results from antimicrobial susceptibility testing assays towards target bacteria belonging to the Alicyclobacillus genus ensure an accurate comparison of the unformulated AA and the produced AA containing microparticles. In conclusion, spray drying and PGSS® microparticles proved to be potential encapsulation systems to control the release of AA.

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MICROBIAL SYNTHESIS OF COMMERCIALLY IMPORTANT FLAVOR AND FRAGRANCE COMPOUNDS

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aldehydes, biotransformations, flavors and fragrances, lactones

In the 21st century, more and more attention is being paid to search processes that correspond to the principles of green chemistry which constitute an alternative to classical chemical methods. Biotechnological solutions of obtaining chemical compounds, which include biotransformations, have been developed very intensively. The use of whole cells of biocatalysts in Solid-State Fermentation (SSF) and Submerged Fermentation (SmF) allows for simultaneous conducting of many enzymatic reactions. It is also an economically viable solution characterized processes by high efficiency. Due to the large variety of microorganisms and the complexity of their enzymatic systems, application them in the form of whole cells allows to obtain products unattainable by other methods. Consumers increasingly choose products of natural origin, paying attention to how a given product was formed. Flavor and fragrance compounds consist a large group, which includes, among others, lactones, aldehydes and arylpropenes. Lactones primarily are responsible for taste and smell of many food products, and also have a wide spectrum of biological activities. Compounds with the aromatic ring as well as aldehydes are commonly found in the essential oils of many plant species. Due to their wide biological activity, they are often used in the food, perfumery, pharmaceutical and cosmetic industries. The aim of our research is developing of microbial processes for synthesis of compounds with lactone moiety, aldehydes and derivatives of arylpropenes. Besides, we are interested in determination of catalytic properties of selected strains of bacteria and fungi using various biotechnological techniques. The studies to obtain whisky lactones were conducted in SmF [1] and SSF [2] using by-products of the oil industry (oilcakes), which are a cheap alternative comparing to medium components dedicated to microorganisms. The other research concerned the use of selected bacteria and fungi to obtain a number of compounds with the aromatic ring. As a result of the transformation of isosafrole with selected fungal strains, piperonal with high yield was obtained [3]. Moreover, a two-step biocatalytic method for obtaining oxygenated derivatives of selected arylpropenes was developed [4]. Finally, the reduction of natural benzoic acid derivatives to produce the corresponding fragrant aldehydes was studied [5].

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ENCAPSULATION OF *BIFIDOBACTERIUM ANIMALIS* SUBSP. *LACTIS* INTO COMPOSITE BIOPOLYMER MICROPARTICLES

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KEYWORDS:
alginate composite, agar, casein, probiotic bacteria encapsulation, structure-properties relationship

The probiotic bacteria Bifidobacterium animalis subsp. Lactis (BB-12) were encapsulated in calcium alginate, combined either with agar or a mixture of agar and casein. The molecular interactions within the composite matrix, primarily hydrogen bonds and electrostatic interactions between the biopolymers and calcium ions, as well as the presence of the encapsulated bacteria, had a complex influence on the structure and physicochemical properties of the composite. These composites showed distinct surface characteristics, with a granular structure and spatial orientation of granules on the alginate/agar/BB-12 surface, while a linear arrangement was observed on the alginate/agar/casein/BB-12 surface. Both composites demonstrated highly organized internal structures and displayed viscoelastic solid-like behavior.The alginate/agar/BB-12 composite showed higher values of storage modulus, yield strength, and yield point, suggesting enhanced stability in diverse physical environments compared to the alginate/agar/casein/BB-12 composite. These mechanical properties, along with their good thermal stability, indicate that the composites possess a well-structured internal network. The rheological characteristics of both composites supported these observations, further confirming the orderly arrangement within the material. Despite the structural differences between the two composites, the release of the encapsulated BB-12 bacteria followed a Fickian diffusion mechanism. This means that the rate of bacterial release was governed by diffusion through the composite matrix. The study's findings provide valuable insights into the complex interactions between probiotic bacteria and alginate-based composite materials. Understanding these interactions is key to improving the stability, structure, and performance of such composite systems in potential applications, such as probiotic delivery systems. These results offer a better understanding of how bacterial cultures interact with alginate composites, contributing to future advancements in the development of probiotic encapsulation technologies.

THE OLIVE MOTH (PRAYS OLEAE BERN.) ATTRACTION TO VOLATILE COMPOUNDS OF OLIVE CANOPY

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KEYWORDS:
insect pests, non-chemical control, olive, integrated pest management, volatile organic compounds

The olive moth (Prays oleae Bern.) is one of the most important pests in olive cultivation. In line with the objective of the European Green Plan to reduce the use of chemical pesticides, there is an urgent need for effective non-chemical pest control methods. According to current knowledge, insects find their plant hosts through volatile organic compounds (VOCs) emitted by the plants, but the interaction between olive trees and olive moth has not yet been studied. The most damaging olive moth generations are those that attack and feed on flowers (antophagus) and fruits 4 to 6 mm in size (carpophagus). Therefore, this study aims to identify the VOCs in olive flowers and fruits of two cultivars susceptible to P. oleae infestation to select those that could attract said pest and test their attractiveness in an olive grove. The composition of VOCs in the flowers and fruits of Lastovka and Oblica cultivars was determined by headspace gas chromatography-mass spectrometry with solid-phase microextraction (HS-SPME-GC-MS). Four different volatile blends were prepared, composed of the most abundant VOCs: two from flower volatiles (one from Lastovka and Oblica) and two from fruit volatiles (one from Lastovka and Oblica). These blends were tested in an olive grove with delta RAG traps, both with and without the addition of olive moth pheromone. The experiment consisted of ten treatments with two control variants (one with an empty trap and one with pheromone only), each repeated three times. From June to August 2023, the number of male and female moths was recorded weekly, and the trap bases and volatile dispensers were replaced. The pheromones were replaced every four weeks following the manufacturer's recommendations. The results showed that two blends containing Lastovka and Oblica floral volatiles in combination with pheromones were statistically the most attractive to olive moths. These results indicate that flower volatiles were significantly more attractive than fruit volatiles, suggesting that flower volatiles can significantly increase the attractiveness of pheromone traps and provide an effective non-chemical method of olive moth control. This is the first study of interaction between olive tree VOCs and olive moth so it offers an innovative and promising approach for integrated pest management in olive cultivation that is compatible with environmental sustainability goals. Future research will optimise these volatile mixtures, understand their long-term effectiveness, and evaluate their impact on non-target species.

NUTRITIONAL PROFILE OF PUMPKIN PULP AFTER ULTRASONIC PRE-TREATMENT AND VACUUM DRYING

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KEYWORDS:
pumpkin pulp, pumpkin by-products, ultrasound, vacuum drying, chemical composition

Pumpkin fruits are seasonal and susceptible to microbial, enzymatic and chemical degradation, which has a negative impact on the desired quality. To avoid the loss of chemical compounds responsible for the specific sensory and nutritional properties of pumpkin, dehydration would be a valuable solution. Although dehydration reduces water activity to a level that can extend the shelf life of food, special attention should be paid to the selection of appropriate drying methods that can prevent damage to the food in terms of preserving its physical and chemical properties. Considering that drying is a cost-effective process, other technologies such as high pressure, ultrasound, microwave energy, pulsed electric fields, etc. have been used as promising tools to improve drying.

Considering these current technological aspects, the aim of the present work was to describe the application of ultrasound as a pretreatment for vacuum drying of pumpkin pulp. Ultrasonic pretreatment was carried out at an amplitude of 30, 60 and 90 % for 30, 45 and 60 minutes, followed by vacuum drying at 60 °C and 100 mbar. The results of the chemical analysis, i.e. moisture, ash, fat and fatty acids, fibre, proteins and sugars, showed that the pre-treatment in combination with vacuum drying preserves the determined parameters. The combination of ultrasonic pretreatment and vacuum drying would therefore be an innovative and useful approach to extend the shelf life of the pulp while preserving the nutritional properties. In addition to these results, this work also shows that significant amounts of seeds and peels generated during the preparation of the pulp for pretreatment and drying could also be utilised. The results of the analysis showed that both the peels and the seeds are rich in nutrients, especially fibre, fat and fatty acids. Therefore, the by-products that are normally discarded and damaged by moisture can be dried, stored and used as a nutrient-rich food supplement.

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DETERMINATION OF RHEOLOGICAL PROPERTIES IN FUNCTIONAL JELLY PRODUCTS BASED ON STRAWBERRY AND STRAWBERRY TREE FRUIT

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KEYWORDS:
Functional food, strawberry, strawberry tree fruit, texture, particle size distribution, rheology

In recent years, consumers are increasingly looking for functional foods that offer both nutritional and bioactive benefits to improve their health. Strawberry (Fragaria × ananssa Duch.) and strawberry tree fruit (Arbutus unedo L.) as raw materials offer significant potential for the development of functional products with high bioactive content. Nevertheless, their suitability for processing into jelly products that could serve as functional foods has not yet been sufficiently explored, although both consumers and industry are striving for towards sustainability and Industry 4.0. In addition, there is a growing threnд towards the use of by-products for the enrichment of functional products. Therefore, the aim of this work was to evaluate the basic rheological parameters i.e., the textural properties (firmness, consistency, cohesiveness, and viscosity index) and particle size distribution in the technological process of the production of functional jelly products. Samples of extra jams from strawberry and strawberry tree fruit were produced with different types of sugar (sucrose vs. fructose) and varying proportions of aqueous extracts of strawberry tree leaves (0 %, 15 % and 30 %). Fruit type significantly influence on all measured textural properties and the particle size distribution values, d (0,1), d (0,5), D (3,2), and D (4,3). In contrast, the type of sugar did not affect the textural properties, while increasing the amount of extract showed a trend to decrease. A comparison of the textural properties with the particle size distribution results showed that the samples containing strawberry tree fruit samples with a higher proportion of smaller particle diameters tended to have higher values of all observed textural properties. The results of this study show that both strawberry and strawberry tree fruit have significant potential for the development of functional jelly products, especially when high quality extracts are included. Further research is necessary to explore the nutritional, bioactive, and sensory potential of functional jelly products developed by using strawberry, A. unedo fruit and leaves extracts as they can offer synergistic benefits, enhanced antioxidant activity, making them more appealing to consumers.

HYDROLATE FRACTION OF COFFEE AND COFFEE BY-PRODUCTS AS A SOURCE OF VOLATILE COMPOUNDS

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KEYWORDS:
coffee, coffee by-products, hydrodistillation, silver skin, spent grounds, volatile compounds

The expansion of the coffee roasting and brewing industry has led to an increase in coffee by-products such as silver skins (CSS) and coffee grounds (SCG), which are still not fully utilised. Unlike roasted coffee, there is no tradition of utilising them for human consumption. Considering the current status of CSS and CSG, their valuable properties and the global trend towards sustainable reuse of food by-products, the further valorization of CSS and SCG should be promoted. The present work therefore describes the idea of how they can be reused for the explosion of volatile compounds, opening up the possibility that they can be used in reformulated foods and dietary supplements while reducing coffee residue pollution. This paper describes the application of the Clevenger hydrodistillation technique, which has not yet been used for the extraction of volatile compounds from coffee and coffee by-products and the production of coffee and coffee by-products in the form of hydrolates. Hydrolates are aqueous solutions saturated with water-soluble or emulsified volatile compounds that remain after the hydrodistillation process. The volatile compounds in the hydrolates of coffee and coffee by-products were determined by GC-MS analysis after HS-SPME on DVB/PDMS fibres. The GC-MS results show that the composition of SCG and CSS hydrolates differs from that of hydrolates from green or roasted coffee, especially with regard to certain types of volatile compounds. SCG and CSS hydrolates were rich in aldehydes (47.56% and 21.45%), followed by alcohols (8.09% and 7.14%), ketones (5.31% and 13.41%), phenols (5.37% and 7.04%) and pyrazines (2.84% and 4.25%). Total acids (11.03 %), for example, were only detected in the SCG hydrolates, with hexanoic acid (4.61 %) predominating. A high yield of volatile aldehydes was observed in SCG hydrolates (47.56 %), twice as much as in green or roasted coffee hydrolates, with (Z,Z)-deca-2,4-dienal dominating, followed by hexanal (7.89 %). The CSS contains considerable amounts of oxygenated sesquiterpenes (13.53 %), the predominant compound being t-cadinol (11.15 %). The results indicate that the coffee by-products SCG and CSS, which are produced after the roasting process or during the preparation of coffee beverages, can serve as a good substrate for the production of hydrolates with high aldehyde content. Due to the high content of volatile compounds, especially the aldehydes produced in this way, the coffee by-product hydrolates could contribute to a fresh and fruity taste and be used as an additive to enrich the flavour of various foods.

PHENOLIC CONTENT AND PHYSICOCHEMICAL PROPERTIES OF SOME ALBANIAN HONEY SAMPLES FOR THERAPEUTIC USE

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KEYWORDS:
diastase number, HMF, physicochemical, TPC

The aim of this work is to evaluate the physicochemical properties and total phenolic contents of some multi-floral and monofloral honey collected from some regions in Albania. The majority of samples were classified as multi-floral and the others were mono-floral. The *Polyfloral* and *Arbutus* honey had the highest acidity, while *Salvia* honey showed the highest conductivity (0.949 mS/cm) among all. The highest diastase activities and the lowest HMF contents were determined in the *Salvia* honey. Accordingly, the highest total phenolic content was determined in the *Salvia* honey followed by *trifolium, thymus, polifloral, chestnut* honey. Based in correlated data of total phenolic content with physicochemical indexes a significant correlation was determined between the total phenolic content and DN ($p = 0.01$). Consequently, the monofloral *Salvia ufficialis* honey could be recommended health purposes due to its total phenolic content together with relatively lower HMF content and higher diastase activity. Considering that north of Albania is the largest *Salvia ufficialis* honey producer region in Albania, this work could be a good recomandition to grow the production of this type of honey with the high TPC level to be used for therapeutic and wound healing assays.

INFLUENCE OF COMMON COPPER FUNGICIDES AND LOW-COPPER PRODUCTS USED IN OLIVE DISEASE CONTROL ON OLIVE OIL QUALITY

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KEYWORDS:
copper residues,
Olea europaea L,
olive peacock disease,
sustainable disease management

Olive leaf spot disease is caused by Venturia oleaginea (Castagne) Rossman & Crous (the anamorph: Spilocaea oleaginea), which exclusively attacks the olive tree. It is one of the most widespread and most dangerous fungal diseases of the olive. Today, olive leaf spot is a significant and serious problem in almost all olive groves worldwide. It affects the fertility of infected trees and its recurrence year after year damages entire olive trees, especially the young trees. Olive leaf spot is mainly controlled with copper-containing fungicides, but their intensive use has a negative impact on the environment and biodiversity in olive groves. However, the accumulation of copper in the soil, the risk of pollution of surface waters and possible copper residues in olive fruit and olive oil give cause for concern about the use of copper fungicides, which is why the European Commission is seeking to reduce or eliminate their use in agriculture. To achieve this, effective alternative methods to control olive leaf spot are needed to reduce the damage by reducing the use of copper fungicides. The aim of this study was to investigate possible copper residues in olive oils after the intensive use of copper fungicides commonly used to control olive leaf spot and of low-copper products. In addition, qualitative parameters and sensory analysis of the olive oils were carried out to investigate the possible influence of the treatments applied on oil quality. The study was conducted in an olive grove in Kaštel Novi and five copper-containing products were applied several times in 2023. In October, the olive fruits for each applied treatment were harvested and processed with a laboratory olive oil mill. The olive oil samples were stored in dark brown glass bottles without headspace at 16-18 °C for further analysis. The oil yield and analysis of the qualitative parameters, phenolic content and sensory analysis of the olive oils obtained were determined according to the protocol laid down in the EU regulations. The copper content in the olive oils was measured by triple quadrupole mass spectrometry with inductively coupled plasma (ICP-QQQ). The treatments applied resulted in significant differences in the analyses performed. One of the most important results is that even in the treatments with the highest copper concentrations, the residues in the oil were below the legally permitted limits for oils.

IMPACT OF CHITOSAN EDIBLE COVERING ON THE CAROTENOID COMPOSITION OF MANDARIN FRUIT DURING

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KEYWORDS:
chitosan, mandarin fruit, carotenoids, HPLC, extraction

In recent years, biodegradable edible coatings have garnered considerable interest as a sustainable alternative to traditional food packaging methods. Among these, chitosan has emerged as a favored polysaccharide coating for various fruits, owing to its effectiveness in reducing moisture loss, inhibiting browning, and preventing fungal infections. This study investigates the impact of chitosan edible coating on mandarin fruit, with a particular emphasis on the composition of individual carotenoid components during a four-week cold storage period. Carotenoid compounds were extracted from pulp and peel prior to high-performance liquid chromatography (HPLC) analysis. The identification of individual carotenoid compounds in the extracts was confirmed through liquid chromatography-mass spectrometry (LC-MS). At the onset of cold storage, beta-cryptoxanthin was identified as the most prevalent carotenoid in mandarin fruit, followed by violaxanthin, beta-citraurine, and zeaxanthine. The beta-cryptoxanthine levels were higher at the end of storage, and the levels of violaxanthine, beta-citraurine, and zeaxanthine decrease. Chitosan edible coating effectively preserves the carotenoid composition of mandarin fruit during cold storage, with beta-cryptoxanthin being the predominant

HYDROLATE FRACTIONS OF COFFEE AND COFFEE BY-PRODUCTS AS A SOURCE OF PHENOLIC COMPOUNDS

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KEYWORDS:
coffee, coffee by-products, hydrodistillation fractions, phenolic compounds, UPLC-MS2

Coffee silver skin (CSS) and spent coffee grounds (SCG), which are produced during the roasting of green coffee (GC) and the brewing of roasted coffee (RC), are normally disposed of in the environment. In the search for alternatives for their use, the current work expresses the idea of reusing them for the extraction of phenolic compounds, which opens up the possibility that they could be used in reformulated foods and dietary supplements while reducing coffee residue pollution.
Considering that the extraction process is the most important step to obtain bioactive compounds, the present work describes the application of Clevenger hydrodistillation, which uses purified water and is environmentally friendly. Thus, this work shows how to utilize the hydrolates formed during the hydrodistillation of coffee by-products (CSS and SCG) and how to supplement them with coffee, i.e. GC and RC as starting materials from which CSS and SCG were formed. The results of the UPLC-MS2 analysis show that of the identified compounds, caffeine was found in the highest amounts, ranging from 2.28 to 15.13 mg/L depending on the hydrolate analyzed. The caffeine content increased from green to roasted coffee hydrolates, indicating that the roasting process has a significant impact on caffeine production. CSS and SCG hydrolates contain the highest caffeine content and high levels of caffeoylquinic acids, so they can be used as a natural source of caffeine and acidic food additives. In addition to CSS and SCG, the hydrolates from RC had the highest content of caffeineoylquinic acids (5- and 3-). The 3-feruloylquinic acid content was also high in the hydrolates from RC, SCG and CSS, indicating their valuable bioactive composition and further potential applications as antioxidants. This emphasizes their continued use as a cost-effective source of phenolic compounds.

FLAXSEED PROTEIN HYDROLYSATES ENHANCE LIPID ACCUMULATION IN ADIPOCYTES

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KEYWORDS:
flaxseed protein hydrolysate, adipocytes, lipid accumulation, cellular agriculture

Flaxseed oil-cake is a byproduct of flax oil production and is often treated as a low-value biomaterial with limited applicability, despite its high protein content. Using flaxseed proteins as a substrate in novel food technologies, like cellular agriculture, remains largely unexploited.
This study aimed to explore the effects of flaxseed protein hydrolysates (FPH) on lipid accumulation in adipocytes *in vitro*. Proteins were isolated from flaxseed oil-cake and hydrolysates were prepared using two different microbial proteases. Hydrolysates were characterized and their effect on proliferation and differentiation of mouse adipocytes (3T3-L1 cells) were examined by quantifying accumulated lipids and cell viability in growth media supplemented with FPH. The results showed that protein digestion profile of each protease varied significantly, resulting in different peptide size. One of the hydrolysates (FPH1) was predominantly composed of low MW peptides (<5 kDa), while the other (FPH2) contained peptides with a wide range of MW, including some over 50 kDa. The effects of FPH on 3T3-L1 cell viability were assessed by supplementing cell culture media with a wide concentration range of hydrolysates. None of the FPH exhibited cytotoxic effects on cells in the preadipocyte phase at concentrations below 2 mg/mL. Upon triggering cell differentiation, both FPHs had similar impacts on adipogenesis. Adding FPH led to a significant increase in lipid accumulation and a decrease in total cell number. These effects were more prominent in cultures with reduced amount of serum in media. FPH1 showed the strongest cytotoxic effect during cell differentiation, giving the highest lipid-per-cell content. The overall lipid quantity was highest in cell cultures supplemented with 0,1 mg/mL FPH2 regardless of serum quantity.
Cellular agriculture refers to the in vitro production of animal and plant-based products with minimal or no direct use of farm animals and plants. This innovative approach offers a promising solution to the growing challenges of food demand and environmental devastation. Given that lipids play a crucial role in the meat flavor, incorporating in vitro obtained animal fats into meat alternatives could mimic the aroma and texture of real meat. Our data indicates that FPH can be used as a media supplement to boost lipid accumulation in adipocytes, potentially enabling more cost-effective production of meat alternatives.

PRODUCTION OF AN INNOVATIVE FUNCTIONAL FOOD SUPPLEMENT BASED ON GOAT'S MILK

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KEYWORDS:
goat milk, yogurt, functional food, organic drink

The advantages of goat's milk are increasingly highlighted in nutrition due to its easier digestibility, fatty acid composition, and the presence of bioactive substances beneficial for preventing or treating certain health conditions. It is particularly recommended for individuals with intolerance to cow's milk proteins due to its hypoallergenic properties. Growing consumer awareness of health issues is contributing to a rising demand for functional foods, including therapeutic functional dairy products. "Powerbiotic," a product resulting from the successful collaboration between researchers from the Faculty of Agriculture and the dairy company Capra Domestica Ltd., has attracted interest in the bio/eco functional food market in Croatia, as well as in the EU, Asia, and the Middle East. Powerbiotic is an organic drink based on goat's milk, containing standard yogurt cultures *Streptococcus thermophilus* and *Lactobacillus delbrueckii ssp. bulgaricus*, as well as probiotic strains *Bifidobacterium animalis subsp. lactis* BB-12, *Lactobacillus acidophilus* LA-5, and inulin. The goal of this research is to transform the existing liquid Powerbiotic into a next-generation functional food supplement in dehydrated form through the process of lyophilization. This process will retain the product's characteristics and functionality while extending its shelf life, enhancing safety, and reducing transportation costs due to the decreased product weight (approximately 10% of the original weight), facilitating its placement in the global market. The consumption of the new dehydrated product will remain simple for the end consumer, as it can easily be reconstituted to its original liquid form by mixing with water. Based on previous preliminary research and the developed existing liquid Powerbiotic, the development of a prototype for the next-generation functional food supplement "Powerbiotic" in dehydrated form is expected. This includes establishing the production method in laboratory conditions, defining its physicochemical and nutritional composition, testing the viability of probiotic strains, assessing the sensory characteristics (preservation of aroma and taste), and determining the shelf life from the moment of lyophilization. Additionally, the physicochemical composition, nutritional values, and microbiological analyses of goat's milk and the existing/new Powerbiotic product in both liquid and dehydrated states will be compared. The development of this product will lay the foundation for new innovative goat milk-based products using the lyophilization process, extending shelf life while reducing the need for a cold transportation chain (4°C) and production costs. This will facilitate easier market placement and enhance the competitiveness of Croatian producers in the EU and global markets.

SPECTRO-FLUORIMETRIC DETERMINATION OF THE RIBOFLAVIN CONTENT IN ENERGY DRINKS

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KEYWORDS:
energy drinks, riboflavin, spectrofluorimetry, standard addition method

Riboflavin (vitamin B2) is an essential vitamin that is important for the normal functioning of metabolic processes in organisms. Due to the structure of the molecule, riboflavin has the ability to fluoresce when excited at 444 nm, which enables its quantification using various methods based on fluorescence detection. Natural sources of riboflavin are foods of plant origin, milk and eggs, but commercial foods such as energy drinks also contain it. Although riboflavin has no toxic effects, the amount contained in some energy drinks exceeds the recommended daily intake. The aim of this study was to determine the concentration of riboflavin in energy drinks available on the Croatian market using the spectrofluorimetric method. Spectrofluorimetry is used due to its simplicity, specificity and sensitivity as well as its low cost compared to other analytical methods. The results obtained, i.e. the concentrations measured in this study, show that the spectrofluorimetric method is an effective method for determining the riboflavin concentration in energy drinks. In addition to the measured concentrations, which are generally consistent with the declared ones, the accuracy of the method for determining the riboflavin concentration in energy drinks is confirmed by the results of the standard addition method.

CHALLENGES IN DEVELOPING 3D-PRINTED FUNCTIONAL FRUIT AND DAIRY PRODUCTS

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KEYWORDS:
3D food printing, functional products, rheological properties

Three-dimensional food printing (3DFP) technology offers the innovative capability to create functional and personalized foods in custom shapes. This study focuses on the challenges in developing recipes for functional fruit and dairy products suitable for extrusion-based 3DFP. The development process began by formulating mixtures using fresh skimmed or partially skimmed cheese, fresh fruit purees and/or vegetable powders, and varying concentrations of hydrocolloids. One significant challenge in developing 3D-printed functional fruit and dairy products is achieving the desired texture, flavour, and nutritional profile while maintaining structural integrity during printing. Ensuring food safety and stability throughout production and storage also presents significant hurdles. Key parameters in development include mixture viscosity and product colour stability. Viscosity is critical for smooth and consistent extrusion, which is essential for reproducibility and achieving the desired form. Minimal deviation from the chosen form is crucial for sustainability and large-batch production. Due to the high water content in fruit pulps, adding hydrocolloids increases the dry matter proportion, enhancing viscosity and creating a mixture suitable for 3D printing without spilling. By incorporating 1% guar gum powder and 20% cornstarch into store-bought apple and mango pulps, as well as laboratory-prepared apple pulp, the mixtures achieved the desired properties for successful printing. Shapes printed at 35°C have a higher yield compared to those printed at 25°C due to lower viscosity at the higher temperature, which allows the mixture to flow more easily through the nozzle. 3D-printed functional dairy products with the addition of guar gum solution, and its combination with beetroot powder, significantly impacted the apparent viscosity of both lean and semi-fat cheese mixtures. Skimmed cheese-based mixtures proved more suitable for 3DFP, offering better performance and efficiency. These mixtures also exhibited a higher average extrusion speed than semi-fat cheese mixtures. However, fresh cheese is a highly conducive medium for microbial growth, with some samples exceeding the recommended microorganism limit by the seventh day of storage. Additionally, colour change assessments revealed noticeable shifts over the storage period. With further refinement, 3DFP has the potential to revolutionize the production of personalized and functional fruit and dairy products.

Session C:

GREEN TECHOLOGIES

ENHANCING GROWTH PROFILES OF MICROALGAE WITH A SPIRAL BAFFLE MEDIATED PHOTOBIOREACTOR DESIGN

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KEYWORDS:
Bioreactor design, growth curve, life cycle assessment, microalgae, sustainability

This study summarizes an investigation of microalgae bioreactor design and growth rate. The research compares microalgae cultivation processes performed at a laboratory scale under sterile conditions and using a light source, and processes performed in non-sterile bioreactors fed with natural light. The study includes unit operations such as microalgae cultivation, harvesting, and drying of harvested biomass. System limits include water and electricity consumption. Based on data obtained from laboratory-scale experiments, the amount of biomass obtained from the BG-11 growth medium, and the growth rates observed in different photobioreactors are examined. The novel spiral apparatus design ensures air bubbles travel without merging, maintaining a consistent bubble size regardless of the column height in the PBR system. This study uses the LCA (Life Cycle Assessment) method to evaluate the environmental impacts of microalgae bioreactor design and provides a comprehensive analysis of various parameters. Considering the potential advantages of the integrated systems, this paper evaluates the potential economic and environmental advantages of incorporating microalgae into building facades, as well as suggesting design principles for PBR systems that maximize growth and production while minimizing environmental effects.

THE ROLE OF FUNGAL BIOTECHNOLOGY IN DEVELOPMENT OF CIRCULAR AND SUSTAINABLE BIOECONOMY

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KEYWORDS:
bio-based products, circular and sustainable bioeconomy, filamentous fungi

Anthocyanins (ANCY) are valuable compounds with many applications in the agro-food industry. While traditional plant-based production is the primary source of ANCY, it takes a long time and yields an inconsistent quality of ANCY, necessitating the exploration of novel, sustainable resources. This study aims to investigate the potential of endophytic fungi associated with purple potato to produce ANCY, offering a green and sustainable alternative to conventional methods. The endophytic fungus isolate ZS5, was isolated from purple potato and can produce water-soluble purple pigments. Morphological and molecular characterization identified the isolate as Fusarium *oxysporum* ZS5, sharing 100% homology with *F. oxysporum*. The pigment had a characteristic absorption peak at 520 nm, and high solubility in water, ethanol, and methanol solution at low concentration. Optimal production conditions were determined using Response Surface Methodology with Box-Behnken Design, yielding high absorbance of the pigment at an initial pH of 5.0, sugar concentration of 40 g/L, and incubation time of 96 h. Metabolic profiling analysis of *F. oxysporum* ZS5 fermentation products was performed after 96 h at 28°C using LC-MS/MS. Results indicated that the purple pigment contained all major types of ANCY-chromophores (ANCY_CMP), including pelargonidin, cyanidin, peonidin, delphinidin, petunidin, and malvidin. The bioactivity and mode of action of ANCY_CMP were identified via *in-silico* molecular docking studies. The inhibitory effect of pelargonidin was demonstrated on the Glycogen phosphorylase (GP) by the binding of pelargonidin-3-O-glucoside on the GP inhibitor site, potentially inhibiting muscle and liver GP isoforms—a target for antihyperglycemic development. Additionally, cyanidin activated Mammalian Sirtuin 6, is implicated in metabolic and aging-related diseases, suggesting potential applications in cancer therapy. ANCY_CMP also modulated key enzymes and proteins, including α-glucosidase, and α-amylase, ...etc. These interactions contribute to their anti-diabetic, cardioprotective, and anti-carcinogenic, antioxidant, anti-inflammatory and antimicrobial properties, enhancing their value in functional foods with potential applications as bioactive agents. This research highlights the first report for discovering of a novel sustainable resource for production of all major types of ANCY_CMP from endophytic fungus *F. oxysporum* ZS5, which offers a controlled and scalable production for industrial applications as a potential alternative to the traditional plant-based production sources.

A RIGOROUS APPROACH TO MODELLING OF BIOMASS GASIFICATION

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KEYWORDS:
Biomass gasification, bio-syngas production, kinetic modelling, rigorous gasifier model, gasification modelling, green hydrogen, process design

Biomass gasification is an alternative to replace fossil fuels (e.g., coal and natural gas) as the feedstock for the production of syngas. The simulation and design of biomass gasifiers are not straightforward due to the intrinsic complexity of the feedstock and reaction occuring within the system. Biomass gasification takes place in different steps and it is split into thermal volatilization and decomposition via pyrolysis and the gasification itself:

1. Pyrolysis and devolatilization – biomass starts degrading and it produces volatile species (mainly CO_x, CH_4, H_2, H_2O) and tar (including alcohols, aldehydes, and ketones),
2. Secondary pyrolysis – the heaviest molecules in the tar undergo a further thermal decomposition producing additional light compounds.
3. Gasification – the injection of steam and/or oxygen sparks the partial oxidation of the residue tar and methane.

Simulations are often done in Aspen Plus using simplified approaches. For instance, pseudo components or chemical classes (e.g., tar) are considered and the pyrolysis process is defined based on yield/conversion models. The description of pyrolysis is challenging due to the wide plethora of produced species. This simplified approach is essential to get preliminary results but does not fully qualify the system. For instance, the process yield and the distribution of the products change with the operating conditions, mainly temperature, and the feedstock quality. When one of these parameters is modified, the process yield should be updated based on experimental measurements. This explains the need for more rigorous modelling. In the present work, we adopt the approach described in other activities. The general idea is to implement kinetic models and true molecules to define the tar fraction. The number of species is kept as the lowest as possible thanks to kinetics lumping. Lumped kinetics effectively describes the evolution of the system by accounting for a limited number of chemical molecules and reactions. The kinetic models are retrieved from the literature. We considered Ranzi et al. and Chen et al. for biomass thermal pyrolysis and secondary pyrolysis of tar, respectively. The gasification is modelled by exploiting the recommended kinetics in Chaurasia, while, Groeneveld and van Swaaij is considered for the char gasification. The model has been implemented in COCO (CAPE-open to CAPE-open) COFE (CAPE-open Flowsheet Environment) v3.6, a Computer-Aided Process Engineering (CAPE) compliant license-free simulation software developed by AmsterCHEM. The results show a good accuracy, i.e., error below < 5%, against data (sensitive and here not reported).

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Webpage - HYIELD: Europe's first industrial-scale waste-to-hydrogen plant.

MAXIMIZING GLUCOSE DEHYDROGENASE PERFORMANCE IN 3D PRINTED MICROREACTORS WITH VARIOUS IMMOBILIZATION STRATEGIES

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KEYWORDS:
enzyme activity, glucose dehydrogenase, gel immobilization, microreactors

Enzymatic reactions are of great importance in a number of industrial processes, e.g. in the production of food, pharmaceuticals and biofuels. One of the biggest challenges in using enzymes for industrial applications is maintaining their stability and activity over a long period of time, especially under harsh operating conditions. To solve this problem, enzyme immobilization techniques have been developed in which the enzymes are fixed or enclosed on solid supports. Immobilization offers several advantages, including improved stability of the enzymes, their reusability and easy separation from reaction mixtures. In addition, immobilized enzymes can be used in continuous flow systems such as microreactors, where they allow better control of reaction conditions, resulting in higher efficiency and product consistency.

Glucose dehydrogenase is an important enzyme used in various biotechnological applications, especially in the biosensor and biofuel industries, as it can catalyze the oxidation of glucose to gluconolactone with simultaneous reduction of NAD^+ to NADH. However, like many other enzymes, glucose dehydrogenase tends to denature and lose activity over time. Immobilization in microreactors offers a promising solution to these challenges as it provides a controlled environment that can improve the stability and activity of the enzyme.

This study investigates the optimization of glucose dehydrogenase activity and stability in a 3D-printed microreactor using various alginate gel immobilization techniques. The enzyme, glucose dehydrogenase, was immobilized in alginate gel in three different configurations: as beads, on the bottom surface of the microreactor, and on both the bottom and top surfaces. The performance of these immobilization strategies was evaluated by measuring the reactivity and stability of the enzyme at different residence times. The results showed that the configuration with enzyme-impregnated gel applied to both the top and bottom surfaces of the microreactor significantly increased enzyme perofrmance. This work highlights the importance of immobilization geometry in maximizing enzyme efficiency in microfluidic systems and provides insights into the design of more effective and reusable enzyme reactors for industrial applications.

PHYSICOCHEMICAL AND MICROSTRUCTURAL CHARACTERIZATION OF BACTERIAL NANOCELLULOSE OBTAINED BY KOMBUCHA WATERMELON RIND FERMENTATION

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KEYWORDS:
biomaterial, bacterial cellulose, kombucha, food waste, sustainability

In recent years, more research has focused on developing sustainable biomaterials that use renewable resources, including incorporating living biological systems. One of the best biomaterials is bacterial nanocellulose (BNC). Research has shown that agricultural waste can be a cheap and sustainable way of synthesizing BNC, which simultaneously meets the ecological requirements for the disposal and reuse of vegetable residues. Bacterial nanocellulose (BNC) is a multifunctional biopolymer with high crystallinity, specific high degree of porosity, purity, relatively high permeability for liquids and gases, extremely high water absorption capacity, structural strength, ultrafine network structure, and biodegradability.

This study investigated two media based on three different carbon sources for BNC synthesis. The sugars included glucose, fructose, and sucrose in standard HS (Hestrin-Schramm) chemically defined media, each in the concentration of 30 g/L and watermelon rinds complex medium (WMR) with 25 g/L glucose, 21 g/L fructose, and 6 g/L sucrose. During the 12 days of fermentation with Komagateibacter xylinus DSM 2004, the production of organic acids (acetic and gluconic) was measured. BNC yield, pH changes, and residual sugar concentrations were monitored. The scanning electron microscopy (SEM) analysis covered microstructural BNC pellicle morphology and Fourier-transform infrared spectroscopy (FT-IR) chemical composition and crystallinity. The present study showed that the WMR medium provides all nutrients required for K. xylinus growth, supporting the synthesis of BNC with high yield and properties similar to those produced by BNCs with commercially available nutrients.

PLAYING WITH FIRE – CONTROLLING THE (SELF-) DESTRUCTIVE REACTION MECHANISM OF LYTIC POLYSACCHARIDE MONOOXYGENASE

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KEYWORDS:
biomass degradation, electrochemical enzyme assay, enzyme catalysis, lytic polysaccharide monooxygenase

The discovery of lytic polysaccharide monooxygenases (LPMOs) has revolutionised our understanding of the degradation and modification of recalcitrant structural biopolymers in the natural carbon cycle. LPMOs, a distinctive group of monocopper-dependent enzymes found in various organisms, employ a unique Fenton-type chemistry to degrade polymeric substrates. Their reaction mechanism allows for the selective oxyfunctionalisation of C-H bonds in the polymer backbone of their carbohydrate substrates, ultimately leading to the cleavage of the glycosidic bond. However, due to the involvement of highly reactive oxygen species, futile reactions in the absence of suitable substrates lead to rapid loss of activity, which has been described as a major problem for LPMO applications. While the problem of self-inactivation is well documented, little is known about how LPMO activity might be regulated or tuned to minimise self-inactivation in Nature.

In this study, we investigated how physiological conditions affect LPMO activity and stability during the degradation of plant biomass by filamentous fungi. We explored the impact of small carboxylic acids and other potential inhibitors using turbidimetric and photometric assays. Additionally, we employed QM calculations and MD simulations to delve into the inhibitory mechanisms. Our findings revealed that fungal metabolites, such as oxalic acid and citric acid, not only significantly reduce LPMO activity but also shield the enzyme from deactivation. Next, we investigated the effects and physiological relevance of low pH and pH-gradients, which are naturally used by filamentous fungi to control and direct their oxidative power. Using a recently developed H2O2-sensitive amperometric sensor, we demonstrated that combining low pH with oxalic acid completely prevents LPMOs from self-inactivation under conditions that would otherwise lead to rapid loss of activity. Under acidic conditions, this protective effect is linked to the reversible and pH-dependent dissociation of the copper ion from the active site of LPMO.

The results of this work provide unprecedented insights into LPMO catalysis and elucidate how this enzyme can be regulated under physiological conditions to achieve high turnover stability, ensuring sustained activity over extended periods.

THE USE OF DEEP EUTECTIC SOLVENTS IN MICROBIAL REDUCTION AND CHEMO-ENZYMATIC OXIDATION PROCESSES

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KEYWORDS:
Baeyer-Villiger oxidation, biocatalysis, chalcones, lactones

Deep eutectic solvents (DES) are mixtures of two or more components that, at a specific molar ratio, exhibit a significant reduction in melting point compared to their individual constituents. Known as "green solvents," DESs are characterized by low toxicity, low volatility, and the potential for reuse, all of which contribute to their sustainability. These properties make DESs environmentally friendly solvents with the potential to reduce the generation of hazardous waste. As a result, there is growing interest in their application in chemical synthesis, extraction, and biotransformation processes, positioning them as a viable alternative to conventional organic solvents. In microbiological systems, DESs can enhance the solubility and bioavailability of hydrophobic substrates. Moreover, DESs provide a stable medium that can enhance enzyme stability and activity, optimize reaction conditions, and facilitate selective reactions. In our study, we investigated the applicability of various deep eutectic solvents as media in biocatalysis processes, particularly focusing on the reduction and oxidation of carbonyl compounds. Hydrogenation reactions were performed using whole yeast cells as biocatalysts, which enabled the selective reduction of α,β-unsaturated ketones such as benzylidene derivatives of cyclopentanone and chalcones to their respective benzyl derivatives of cyclopentanone and dihydrochalcones. Additionally, DESs were utilized as reaction media in the chemo-enzymatic Baeyer-Villiger oxidation of α-benzylcyclopentanones, leading to the formation of lactone derivatives. In these experiments, lipase B from *Candida antarctica* served as the catalyst. The DES not only acted as the solvent but also contained a component that functioned as the oxidizing agent in the reaction. The influence of reaction conditions on the efficiency of the process was evaluated. Among the esters tested, the highest conversion was obtained in ethyl acetate. The DES composed of choline chloride and UHP was identified as the best among the tested deep eutectic solvents. In summary, our research confirms that DESs show great potential as sustainable and efficient alternatives to conventional solvents in biocatalytic processes.

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CUSTOMIZING A MICROREACTOR FOR CONTINUOUS BIOCATALYSIS: ENZYMATIC ACETOPHENONE REDUCTION IN A DEEP EUTECTIC SOLVENT

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KEYWORDS:
biocatalysis, deep eutectic solvents, enzymatic reduction, enzyme immobilization, microbioreactor.

Green technologies are essential for confronting the fastly changing climate, building healthier ecosystems and promoting sustainable development. Therefore, implementing green chemistry principles, especially the use of green solvents and biocatalysts, is crucial in reducing the environmental impact of widespread chemical processes.

More precisely, continuous biocatalysis is becoming a dominant requisition when transferring a new reaction system to industry. This cut edge technology allows a steady, uninterrupted flow of reactants through the system, leading to several benefits such as process control and efficiency in terms of process stability and productivity. Continuous biocatalytic processes can be performed in miniaturized reactors to facilitate process intensification, help the development of multi-step synthetic pathways with compartmentalized biocatalysts and seamless integration with downstream processes, thereby enabling efficient utilization of biocatalysts across various industries.1 To tackle another green chemistry principle in this research, green solvents are incorporated in the reaction system design. More precisely, deep eutectic solvents (DES) are investigated as promising alternatives to conventional solvents. Due to their economic efficiency and overall greenness, DES are considered for use in the enzyme-catalyzed synthesis of enantiomeric compounds.2,3

Accordingly, this research aimed to establish an environmentally friendly preparation of a chiral pharmaceutical intermediate, (S)-1-phenylethanol, using rationally designed DES. Taking into account considerations such as substrate solubility, as well as enzyme stability, betaine:ethylene glycol with 50% (w/w) water was identified as the optimal reaction media in the alcohol dehydrogenase (ADH)-catalyzed acetophenone reduction. Additionally, following the exciting results in nicotinamide adenine dinucleotide (NAD) stabilization in the same solvent4, the reaction system was designed to regenerate the expensive NAD+ cofactor by adding the second substrate, isopropanol. After assessing the Michaelis-Menten reaction kinetics parameters and ensuring sufficient enzyme load in a batch process, the reaction was transferred to a continuous flow system. Further, cross-linked enzyme aggregate (CLEA) particles were generated using a microfluidic system to enhance the stability of ADH in the flow system.5 Also, a microreactor system between two plates, featuring CLEA-ADH immobilized on the membrane surface was manufactured utilizing 3D printing. In the end, a validated 2D model-based design approach, incorporating time-scale analysis (TSA) with characteristic times, was employed to identify the optimal process parameters and operational conditions.6 Overall, customizing a microreactor for enzymatic acetophenone reduction in deep eutectic solvent offers a more efficient and scalable approach to chemical production.

NATURAL DEEP EUTECTIC SYSTEMS APPLICATIONS IN POLYMER ENGINEERING

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In the current scenario of a worldwide quest for sustainable and "greener" alternatives for current applications, in the past two decades the number of reports on Deep Eutectic Systems (DES) applicability in various situations has rapidly grown. The tailor-made versatility of these eutectics, meaning in practical terms a wide range of chemical and physical properties, has turned them into significant tools in the development of green and sustainable technologies. For this purpose, their use in polymeric applications has been growing and expanding to new areas of development. The present communication presents the progress in the field of DES applied to polymer science and engineering, namely recent applications of DES in extraction and modification, and the early developments on the formulation of DES–polymer products. In this sense, our group has explored DES for the extraction of collagen from blue shark skins which were subsequently processed to render different aerogel structures. This work demonstrated that the presence of DES as solvent allows the preparation of a lightweight, with a sponge-like structure, with high specific area and pore volume. In parallel to this work, we have investigated the possibility to produce injectable hydrogels, formed in situ by enzymatically crosslinking hydrolyzed collagen. DES, as it has been proved in previous studies, is able to promote an increase in thermal and structural stability of enzymes, in particular of horseradish peroxidase (HRP), improving its activity. Hence, HRP was selected to mediate this crosslinking reaction. One of the possible applications of these gels is regenerative medicine. The hydrogel preparation, gelation time, long term stability and mechanical properties were investigated. Moreover, the feasibility of using these gels as drug delivery systems was assessed by studying the compatibility of several non-steroidal anti-inflammatory agents (NSAID's) with the DES of interest. Within the same line of research, we have we developed other DES-based gels, with enhanced lubricating properties, and integrating an NSAID, with improved solubility (≥ 5 times), for local action. Their rheology was characterized in terms of viscoelastic properties (crossover frequency, G' and G'' at walking or running frequencies, temperature dependency, and response to loading forces (shear-rate profile)) and the gels' biocompatibility was also evaluated in vitro with a chondrogenic cell line. The results support the preparation of biocompatible formulations with potential to be used in regenerative medicine. In summary, the combination of DES and polymers is highly promising in the development of new and 'greener' materials. However, there is many questions that remain unanswered and open the doors for future research in this field.

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UTILIZATION SCENARIOS OF WHEY FOR AFFORDABLE AND CLEAN BIOCHEMICALS AND BIOFUELS: A COMPARATIVE PROCESS SIMULATION AND TECHNO-ECONOMIC EVALUATION

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KEYWORDS:
Ethanol, hydrogen, lactic acid, techno-economic evaluation, whey

The valorization of whey, a side-product of the dairy industry, is gaining significant interest due to the high amount of generation, approximately 100 million tons annually, and containing valuable components such as lactose, protein, and other nutrients, which have economic benefits. Due to this composition, whey is a promising candidate for producing valuable biochemicals and biofuels to contribute to a sustainable future and low-carbon society. Herein, this study explored a comparative economic evaluation of whey processing scenarios. Three scenarios were conducted to produce lactic acid, ethanol, and hydrogen with a processing capacity of 500,000 L whey/day. The data for the bioconversion and downstream operation of final product purification was obtained from literature, and the process flow diagrams of industrial-scale production were prepared for each scenario in SuperPro Designer. Also, the protein content of whey was utilized for protein production, and fats were used for whey butter as a by-product. These by-products were used to reduce operational expenses and unit production costs. Based on the key economic results such as a short payback period (PBP), a high return on investment (ROI), net present value (NPV), and internal rate of return (IRR), it was noticeable that whey could be considered as an alternative substrate for biochemical conversion.

LA:Glu:W
2.5% Chitosan
5% DES+Drug

CA:L-Pro:W
2.5% Chitosan
5% DES+Drug

BIOPOLYMERIC MEMBRANES CONTAINING DES FOR TRANSDERMAL DRUG DELIVERY APPLICATIONS

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KEYWORDS:
API solubility, Deep Eutectic Systems, Biopolymers, Dressings, Controlled drug release

The poor solubility of some active pharmaceutical ingredients (APIs) is still one the main challenges in the pharmaceutical industry, since most of them show poor water solubility, hindering treatment efficiency1. Developing novel delivery systems for known APIs is therefore of great importance, not only to overcome some limitations of solid formulations, associated with polymorphism, toxicity, and low bioavailability, but also from a sustainability point of view, since it avoids the need of costly research and clinical trials for new therapeutic molecules. Within this work, different deep eutectic systems (DES) were tested as solvents for some common APIs, namely ibuprofen, lidocaine, naproxen and acetylsalycilic acid. DES are sustainable solvents, that have been reported as good solvents for APIs with low solubility and high permeability2,3. Besides improving API solubility, the use of DES also allows the design of new drug delivery systems. In this work, the addition of a biopolymer (chitosan or gelatin) to the DES-API was tested, allowing to obtain flat membranes. This can be further used for designing dressings for transdermal drug delivery systems. DES, composed of lactic acid:Glucose:H2O, Citric Acid:L-proline:H2O, levulinic acid:choline chloride and lactic acid:choline chloride showed improved solubility of the studied APIs when compared to their solubility in water.

Using gelatin and chitosan, it was possible to obtain DES supported membranes, which were characterized in terms of their composition, mechanical stability, sweeling degree, gas permeation and also, the drug release profile for the studied APIs. The best results were obtained combining DES lactic acid:glucose:H2O with Lidocaine, and 2.5% of chitosan. This work paves the way to adopt more sustainable processes to pharmaceutical product development, using sustainable solvents, polymers and conscious use of API.

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DEEP EUTECTIC SYSTEMS: PAVING THE WAY FOR A GREENER PHARMACEUTICAL INDUSTRY

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KEYWORDS:
green chemistry, sustainability, synthesis, antibiotics, deep eutectic solvents

It is well known that with the increase of life expectancy, the world's population is exponentially increasing, leading to the appearance of new diseases and pathologies and therefore, to an increase production of drugs and chemical-based care products. The pharmaceutical industry faces increasing pressure to adopt sustainable practices amidst growing environmental concerns. This industry is amongst the highest producers of solvent-related waste, having a detrimental effect on the environment. So, it is urgent to find alternative solutions, able to replace these toxic and polluting solvents and processes for the manufacture of pharmaceuticals. Deep eutectic solvents (DES) have emerged as promising green alternatives due to their biodegradability, low toxicity, and versatility in chemical reactions. Their production is 100% atom efficient, and no waste is generated during their production.

In this work, we focused on the synthesis of fluoroquinolones as an example how DES can replace volatile organic solvents in a synthetic pathway. Our results showed that for the total synthesis of ciprofloxacin, a highly prescribed fluoroquinolone antibiotic, DES can play an important role, successfully replacing organic solvents such as dimethylformamide (DMF) or dioxane in most steps. We were able to decrease reaction time and temperature while increasing the reaction yield by using DES as solvents.

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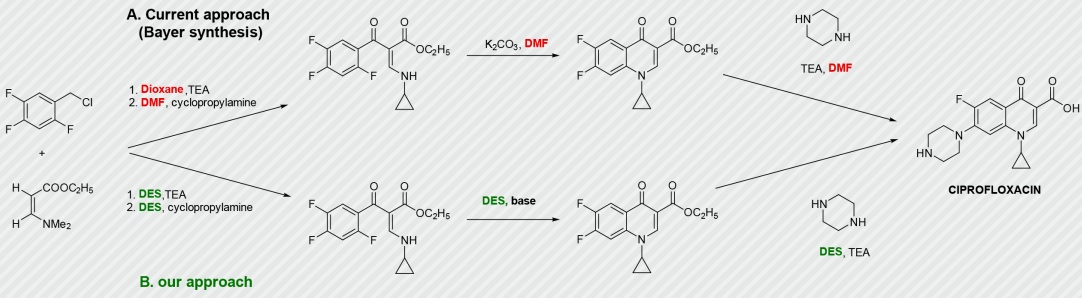

DEEP EUTECTIC SOLVENTS FOR ENHANCED DRUG SOLUBILISATION: ADVANCING FROM SOLVENTS TO DELIVERY SYSTEMS

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KEYWORDS:
Delivery Systems, Eutectogels, NLC hydrogels, Therapeutic Deep Eutectic Solvents

The growing popularity of deep eutectic solvents (DES) in various applications is largely due to their eco-friendly nature, non-toxicity, and tunable properties. In the pharmaceutical field, DES are mainly used to enhance drugs' potential by improving solubility and permeability. That can shift drugs into more favourable categories within the Biopharmaceutics Classification System (BCS), resulting in better efficacy and safety. In our recent study, we employed in *silico* modelling using COSMOtherm software to select appropriate DES for solubilizing active pharmaceutical ingredients. Notably, dissolving azithromycin (AZ) in the selected DES significantly increased its solubility while preserving its antimicrobial activity and stability. Building on these results, we explored novel delivery systems for the newly formed therapeutic deep eutectic solvents (THEDES) with azithromycin, using different strategies for hydrophilic and hydrophobic THEDES.

For hydrophilic THEDES, we developed therapeutic eutectogels (eutectogel-T), testing four different gelators. The successfully produced eutectogels were evaluated for their swelling capacity in gastrointestinal-simulating buffers and their water retention rates.

For hydrophobic THEDES, we used an innovative approach, incorporating a nanostructured lipid carrier (NLC) in an alginate hydrogel system. NLCs with encapsulated THEDES (NLC-T) were formulated into alginate hydrogels using CaCl2 as a crosslinking agent. A design of experiments was employed to optimize the hydrogel preparation process, and dynamic light scattering was used to characterize the NLC-Ts. These NLC hydrogels were also tested for swelling and water retention properties.

The most promising eutectogel-T formulation was Ma:Fru:AZ with xanthan gum as the gelator. The NLC-T hydrogels demonstrated excellent swelling ability and high water retention rates, with an overall superior gel structure and properties compared to eutectogel-Ts. Moreover, the NLC-Ts exhibited remarkable zeta potential and polydispersity index, confirming the viability of this approach. Both gel-based delivery systems for THEDES show great promise as innovative drug delivery methods.

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EVALUATION OF DEEP EUTECTIC SOLVENTS FOR ENHANCED POLYPHENOL EXTRACTION AND ANTIBACTERIAL ACTIVITY OF *Hypericum androsaemum* EXTRACTS

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KEYWORDS:
antibacterial activity, deep eutectic system, Hypericum androsaemum, phenols

This study investigated the application of deep eutectic solvents (DESs) for extracting polyphenols from *Hypericum androsaemum*, a plant valued for its culinary, cosmetic, and pharmacological potential, particularly for its hepatoprotective, anti-inflammatory, and diuretic properties. The research explored a green approach using various DESs based on betaine and lactic acid, including betaine/ethylene glycol (Bet/Eg), betaine/glycerol (Bet/Gly), lactic acid/menthol (La/Men), lactic acid/proline (La/Pro), lactic acid/glucose (La/Glu), and lactic acid-betaine (La/Bet). These DESs were employed in ultrasonic extraction at varying temperatures (30, 45, and 60°C) and extraction times (30 and 60 minutes), with conventional solvents ethanol and water used as control. The extracted polyphenols were analyzed using HPLC and assessed for antibacterial activity against both Gram-negative and Gram-positive bacteria, including *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Staphylococcus aureus*. Chlorogenic acid was the most abundant compound, with concentrations ranging from 16.90 to 796.99 µg/mL, peaking in the La/Glu extract obtained at 60°C for 60 minutes and in the Bet/Eg extract obtained at 60°C for 30 minutes (767.84 µg/mL). Other identified compounds included hyperoside, quercetin, quercitrin, and isoquercitrin. The Bet/Eg system at 60°C for 30 minutes was particularly effective in extracting hyperoside, quercitrin, and isoquercitrin, while the La/Glu extract at 60°C for 60 minutes favored quercetin recovery. Although water demonstrated similar efficiency to the most effective DESs for extracting chlorogenic acid, its efficiency for other polyphenols was significantly lower. In terms of antibacterial activity of selected extracts, water extracts showed the weakest activity despite high chlorogenic acid content, with minimum inhibitory concentrations (MICs) of 12.500-25.000 mg/mL. The La/Glu extracts exhibited more pronounced antibacterial activity, particularly against Gram-positive bacteria (MICs of 0.391 and 0.781 mg/mL for Gram-positive and Gram-negative bacteria, respectively). The most potent antibacterial activity was observed in the Bet/Eg extracts at 60°C for 60 minutes, with MICs of 0.195 mg/mL against B. subtilis and S. aureus and 0.012 mg/mL against E. *coli* and P. *aeruginosa*. This study highlights the effectiveness of DESs in enhancing the extraction of bioactive compounds from H. *androsaemum*, presenting a promising green alternative for obtaining extracts rich in high-value polyphenols with significant antibacterial properties. These findings have potential applications in the food, pharmaceutical, and cosmetic industries.

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EXTRACTION OF PROTEINS AND PHENOLICS FROM AGRO-INDUSTRIAL BY-PRODUCTS USING DEEP EUTECTIC SOLVENTS

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KEYWORDS:
agro-industrial by-products, deep eutectic solvents, phenolics, proteins, sustainable extraction

Sustainable management of natural resources is a critical challenge in the modern world. The processing of agro-food raw materials generates numerous by-products, the rational utilization of which can lead to the production of value-added products. In this context, deep eutectic solvents (DESs) are emerging as effective and environmentally friendly alternatives for extracting valuable compounds from such by-products. DESs are formed by mixing at least two compounds in specific molar ratios, where one acts as a hydrogen bond donor and the other as an acceptor. Common components used to create DESs include quaternary ammonium salts, polyols, amides, carboxylic acids, and sugars. DESs offer several advantages: they are cost-effective, easy to prepare, non-volatile, biodegradable, and exhibit low toxicity, making them promising "green" solvents. This study will present the results of research on the application of choline chloride-based DESs for the extraction of proteins and phenolic compounds from agro-industrial by-products such as oilseed cakes and spent hops. The findings highlight the potential of DESs as efficient and sustainable solvents, demonstrating their capability to enhance the recovery of valuable components and contribute to the valorization of industrial by-products.

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WINERY BY-PRODUCTS AS POTENTIAL SOURCE OF NOVEL FUNGICIDES

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KEYWORDS:
Agricultural applications, antifungal activity, Winery sub-products valorisation, Sustainable extraction

Grape is an important agro-economic activity with more than 77 Mton produced worldwide in 2022. The International Organisation of Vine and Wine estimated that 262 MhL of wine were globally produced in 2022 [1] and it is estimated that 14.5 Mton of grape by-products are generated annually in Europe [2]. The disposal and treatment of these organic materials is a problem of ecologic and economic impact. A key target of the European Commission for 2030 is to reduce the use of chemical and hazardous pesticides by 50%. To address these issues, efforts are underway to replace synthetic pesticides with natural alternatives [3]. Green extraction methods like pressurized fluid extraction have already been used to recover valuable compounds from grape by-products [4-5], such as flavonoids, stilbenes and phenolic acids. This study aims to develop a strategy to extract natural bioactive compounds from winery by-products, namely from red and white stems, leaves, and pomace, with antifungal potential. Winery by-products were processed by supercritical carbon dioxide and subcritical water to recover bioactive-rich fractions. To maximize the extraction of high-valued compounds, the effect of different process parameters, including operating temperature, pressure and time, on the extraction performance (extraction yield and chemical composition) was evaluated. Moreover, and for comparison purposes, conventional S-L extractions using a combination of methanol, water and acetone (6:3:1 v/v/v, respectively) were also performed. All obtained extracts were characterised by HPLC and LC-MS/MS. The conventional extraction method demonstrated higher extraction yields, particularly from red grape materials, achieving a maximum of 48% with red. This increased efficiency can be attributed to the presence of anthocyanins, which are more effectively extracted by polar type solvents. The major flavonols identified included quercetin-3-O-glucuronide, quercetin-3-O-galactoside, quercetin-3-O-glucoside, isorhamnetin-3-O-rutinoside, and kaempferol-3-glucuronide, along with the stilbene resveratrol, all known for their potent antioxidant activity. To evaluate the antifungal potential of the obtained extracts, in vitro antimicrobial and in planta biocontrol activities were determined. The antifungal potential was tested towards Botrytis cinerea (CECT 20973) and Venturia pyrina (CECT 20973) used as a representative target of filamentous fungi that attack vineyards and pear trees, respectively. Antimicrobial susceptibility testing assays were performed in vitro using a well-diffusion adaptation of the standardized method described by the CLSI [6] to determine the susceptibility of nondermatophyte filamentous fungi. The biocontrol activity is being performed in planta using detached leaf assays on tomato plants and pear trees, ideal surrogates for pathogenic interactions with the fungal targets.

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REMOVAL OF AFLATOXIN B1 USING BREWER'S SPENT GRAIN

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KEYWORDS:
brewer's spent grain, biological methods, mycotoxins, sustainability

Mycotoxins, secondary metabolites produced by molds, are harmful to both human and animal health. They can contaminate food and agricultural products at any stage of production, during processing, transport, or storage. Furthermore, they can cause a range of health problems, including both acute and chronic diseases, and therefore need to be controlled to ensure their concentrations do not exceed safe levels. There are several methods for removing mycotoxins, including chemical, physical, and biological approaches. Among these, biological methods are considered the safest and most environmentally friendly. These methods often use microorganisms and adsorbents of either organic or inorganic origin. This study aimed to evaluate the potential of brewer's spent grain for mycotoxin removal, specifically focusing on the removal of aflatoxin B1 from phosphate buffer at pH 7 and citrate buffer at pH 3. Both untreated and acid-hydrolyzed brewer's spent grain were tested as adsorbents. The results showed that both adsorbents successfully removed AFB1 during a 24-hour incubation period, with the acid-treated spent grain achieving the best results, removing over 80 % of the mycotoxin from the buffer.

CORROSION INHIBITION PERFORMANCE OF ARUNDO DONAX L. LEAVES ALCOHOLIC EXTRACT ON FE B500B STEEL IN ACIDIC SOLUTION

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KEYWORDS:
acid inhibition, alcoholic plant extract, carbon steel, green corrosion inhibitor, electrochemical measurements

Corrosion is a destructive phenomenon observed both in daily life and in several industrial applications, causing not only significant economic impact, but presenting also grave ecological as well as human life and safety concerns. Although the addition of organic compounds has been proven successful in mitigating metallic corrosion in various environments, due mainly to their high toxicity, possible replacements are constantly sought. Plant extracts present an excellent environmentally friendly, low toxicity, biodegradable and sustainable alternative to those compounds. In this paper, the inhibition efficiency of the alcoholic extract of Arundo Donax L. leaves is evaluated in the corrosion of Fe B500B steel in 1 M HCl solution in the temperature range of 25–45 °C, using weight loss and electrochemical measurements. The corrosion rate of the steel samples decreased with increasing the extract's concentration in the 5–50 mg L–1 range and increased with increasing temperature. The highest corrosion inhibition efficiency (i.e. 87.37%) was achieved for 50 mg L–1 of the alcoholic extract added. The addition of 50 mg L–1 KI further increased the corrosion inhibition efficiency of the alcoholic extract. Thermodynamic calculations showed that the phytochemical compounds found in the alcoholic extract chemically and physically adsorb on the steel surface, following the Langmuir isotherm.

INFLUENCE OF *MELISSA OFFICINALIS* EXTRACT CONCENTRATION ON BIOSYNTHESIS OF IRON NANOPARTICLES

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KEYWORDS:
biosynthesis, plant extract, iron nanoparticles, concentration, lemon balm

Plant extracts offer an environmentally friendly, simple and cheap way to synthesize nanoparticles compared to traditional physicochemical methods. This approach leverages the natural antioxidant power of bioactive plant components like polyphenols, flavonoids, and organic acids. This study investigated the influence of Melissa officinalis L. (lemon balm) extract concentration (ranging from 2.5% to 100%) on the biosynthesis of iron nanoparticles from a 0.1 M FeCl3 precursor solution. Different properties of the reaction mixtures as well as the resulting powders were determined (pH, conductivity, colour, FTIR, UV-Vis spectroscopy, and the hydrodynamic diameter of particles). Furthermore, the total amount of polyphenols in the extract was determined using the Folin-Ciocalteu reagent and the antioxidant activity using the DPPH method. The results revealed that the mass of the obtained nanoparticles increased with higher lemon balm extract concentrations and that the consumption of bioactive compounds for the synthesis of iron nanoparticles increases with the increase in the concentration of the extract. Additionally, FTIR and UV-Vis spectroscopy confirmed the formation of nanoparticles and the presence of stabilizing functional groups on their surface, likely derived from the plant extract.

PRODUCTION OF CELLULOSE-BASED ENZYME IMMOBILIZATION CARRIER FROM BROWN ONION SKIN

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KEYWORDS:
alkaline liquefaction, brown onion skin, cellulose-based enzyme immobilization carrier, lipase immobilization, semicontinuous solvent flow sequential subcritical extraction

Transformation of brown onion skin (BOS) into a cellulose-based carrier for lipase immobilization using a semicontinuous sequential subcritical extraction involving 96%, 75%, 50%, and 25% ethanol and water was investigated. Obtained solid residue (SEBOS) was subjected to alkaline liquefaction with 10% NaOH to produce a dominantly cellulose-based carrier for enzyme immobilization. Semicontinuous sequential subcritical extraction of BOS resulted with solid residue enriched in crude fibers (BOS - 37.29 ± 1.62 g/100 g d.w.b, SEBOS - 48.55 ± 0.91 g/100 g d.w.b) and 37.22 ± 1.03 mg/g of proteins, 39.86 ± 0.90 mg/g of sugars, 28.26 ± 0.89 mg/g of polyphenols, and 36.21 ± 1.36 mg/g of flavonoids, 9.81 ± 0.39 mg/g of quercetin totally present in extracts. Further enrichment in crude fibers was obtained by alkaline liquefaction of solid residue obtained after semicontinuous sequential subcritical extraction of BOS, resulting with suitable carrier (ALSEBOS)of 70.96 ± 3.01 g of crude fibers per 100 g d.w.b. Obtained carrier had particle size diameter of 246.60 ± 25.98 μm, water holding capacity of 6.20 ± 0.22 mL/g, and showed chemical inertness. Suitability of obtained carrier for immobilization was proven by immobilization by adsorption of Burkholderia cepacia lipase, with immobilized lipase of 233.67 U/g of carrier. Based on the obtained results it can be safely concluded that brown onion skin has great potential to be used for the production of enzyme immobilization carrier with concomitant production of valuable bioactive components present in extracts.

RATIONAL DESIGN OF NATURAL DEEP EUTECTIC SOLVENTS FOR EXTRACTION OF HIGH-VALUE BROCCOLI COMPOUNDS

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KEYWORDS:
broccoli, glucosinolates, green extraction, natural deep eutectic solvents, polyphenols

Broccoli is rich in biologically active compounds, especially polyphenols and glucosinolates, which contribute to the plant's numerous health benefits. Glucosinolate breakdown products help prevent cancer and cardiovascular diseases, while phenolic compounds have antioxidant, antitumor, and vasodilatory effects. Due to the many drawbacks of conventional extraction methods, new trends in extracting valuable plant metabolites focus on producing high-quality extracts with enhanced bioactivity and longer shelf life while minimizing the use of harmful solvents. Natural Deep Eutectic Solvents (NADES), a novel class of eco-friendly solvents, provide a highly versatile and customizable framework for designing extraction processes that yield safe, high-quality plant extracts. Their flexibility in composition allows for the selective extraction of bioactive compounds, making them ideal for applications in the food and cosmetics industries, where natural, sustainable, and effective ingredients are increasingly in demand. However, selecting the right NADES is time-consuming and costly, prompting the use of computational methods for more efficient solvent design.

In this study, the potential of NADES-assisted extraction of polyphenols and glucosinolates from broccoli was investigated, with the aim of developing biologically active and stable liquid extracts. Computational screening was first used to narrow down NADES candidates, followed by extraction, analysis of polyphenol content, glucosinolates profile, antioxidant activity, and stability monitoring. Obtained extracts bioactivity was further tested on skin (HaCaT) and tumor (HeLa) cell lines, Finally, NADES-assisted process's sustainability and profitability was evaluated. Therefore, the general aim of this scientific work is to establish a sustainable preparation of a high-value and stable liquid broccoli extract in NADES, rich in polyphenols and glucosinolates, which can be directly applied in the food or cosmetic industries without additional purification steps. The results showed that NADES-extracted polyphenols and glucosinolates had higher levels and antioxidant effects, with greater stability compared to extracts obtained with ethanol. Finally, the sustainability assessment and S.W.O.T. analysis confirmed that NADES offers exceptional potential for preparing biologically active and stable plant extracts in an environmentally and economically sustainable way.

EFFECT OF TEXTILE WASTEWATER USAGE ON ZINC CONCENTRATION IN SOIL

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KEYWORDS:
zinc, ultrafiltration, reverse osmosis, textile wastewater, agriculture

This study investigates the potential reuse of retentate from a hybrid membrane process with ultrafiltration and reverse osmosis (RO) used in the treatment of textile wastewater (TWW). The reuse potential was assessed by studying the zinc (Zn) concentration in potting soil. In agriculture, the use of wastewater for irrigation is a common practice in areas with water scarcity. Overall, TWW could provide valuable nutrients, but also some harmful pollutants (e.g. biochemical oxygen demand, dyes, heavy metals, etc.). One of these heavy metals is classified as an essential mineral nutrient (Zn) which, if accumulated at optimal level can promote certain cellular functions in plants. In this experiment, the pots were watered with tap water (A), untreated textile wastewater (B), RO retentate (35% recovery) (C) and a 50:50 mixture of RO retentate and tap water (D). Four plant pots were used for each water type, and each pot was irrigated daily with 75 mL of water for 21 days. The results showed that the Zn content in treatment A was significantly higher than in the other treatments. The higher values in treatment A could be due to the dissolution of the anti-corrosion coating used in the tap water pipes. The values of the treatments were in the following order: D < C < B < A. Importantly, all values found were below the levels generally considered. The mobility of Zn is influenced by various properties (e.g. pH, electrical conductivity, organic matter), as Zn plays a crucial role in the formation of chlorophyll. Therefore, achieving optimal levels in the soil is highly recommended for agricultural production. Accordingly, the reuse of retentate could be beneficial to meet the required Zn demand while reducing the improper disposal of wastewater.

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ULTRASOUND - ASSISTED EXTRACTION OF PHENOLIC COMPOUNDS FROM OLIVE LEAVES

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KEYWORDS:
antioxidant activity, olive leaves, ultrasonic-assisted extraction, total phenols

Olive leaves are agro-industrial waste and pose an ecological challenge. As a solution, the principles of sustainability and chemical composition analysis are introduced with the aim of creating innovative products. The aim of this work is to determine the phenolic compounds and antioxidant activity of olive leaves in order to make suggestions for the further use of this type of "waste". For this purpose, ultrasonic extraction (UAE) was performed to determine the influence of ultrasonic extraction parameters on the phenolic composition and antioxidant activity of olive leaves. To determine the optimal extraction capacity, ultrasonic extraction was performed using a 14 mm diameter ultrasonic probe (rated power 200 W) at different extraction times (5 - 40 minutes) and with different extraction solvents (water, 30% and 50% ethanol, v/v). Based on the results obtained, the optimal ultrasonic extraction parameters and solvents were determined to achieve the maximum extraction capacity for the isolation of total phenols. The mass fraction of total phenols and antioxidant activity were determined using spectrophotometric analysis methods. Significantly higher mass fractions of total phenols from olive leaves (1602.51 mg/100 g) were determined after 30 minutes with water as solvent, while achieving maximum antioxidant activity (429.01 mg AAE/100 g). A correlation was found between phenolic content and antioxidant activity in 30 % ethanol (r=0.98) and water extracts (r=0.83). The most important ultrasound parameter to achieve higher antioxidant activity is the polarity of the extraction solvent, and the trend is identical for both extraction types: water > 30 % ethanol > 50 % ethanol. The results obtained indicate the potential of ultrasound-assisted extraction of olive leaves and the extracts obtained from them for the production of innovative products to solve the problem of accumulation of this agro-industrial waste in the future.

EVALUATION OF OLIVE OIL INDUSTRY BY-PRODUCTS AS A SOURCE OF PHYTOSANITARY INGREDIENTS

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KEYWORDS:
Antifungal activity, Detached leaf assay, Natural pesticides, Olive oil by-products

Due to the challenges proposed in the European Green Deal and the Farm to Fork strategy concerning the area of plant protection, one of the European Commission's targets for 2030 is to reduce the use of synthetic pesticides, as they pose long-term hazards to the environment and human health due to their persistence in nature and body tissues. To address these challenges, efforts are being made to replace traditional pesticides with chemicals derived from natural sources. In this scenario, olive oil by-products offer a low-cost and abundant source of bioactive compounds such as carbohydrates, proteins, fatty acids, fibres, minerals, and phenolic compounds. These compounds exhibit various bioactivities, including antioxidant and antimicrobial properties. This work aims to extract bioactive compounds from olive oil by-products and evaluate their antimicrobial potential in eliminating and preventing crop pathogenic fungi. This approach represents a promising strategy for valorising these materials and applying natural bioactive compounds in phytosanitary practices. As a first screening, solid-liquid extraction was conducted using residues from the agro-industrial processing of olive oil, like olive pomace (OP) and olive leaves (OL), with solvents of various polarities (water, ethanol, acetone, ethyl acetate, chloroform, and n-hexane) at different temperatures. The obtained extracts were characterized in terms of total phenolic compounds (TPC) and antioxidant activity. To evaluate their potential as phytosanitary ingredients, in vitro antimicrobial and in planta biocontrol activities were carried out. The antifungal potential was tested towards Botrytis cinerea (CECT 20973) and Venturia pyrina (CECT 20973) used as a representative target of filamentous fungi. Antimicrobial susceptibility testing assays were performed in vitro using a well-diffusion adaptation of the standardized method described by the CLSI. In general, OL extracts showed higher TPC content and more antioxidant potential than OP, achieving maximum values of 2320 µmolTEAC/gextract and 75 mgGAE/gextract both with ethyl acetate, respectively. As expected, the extracts containing more TPC and antioxidant activity were obtained with polar solvents (ethanol, acetone, ethyl acetate). Moreover, compared with commercially available antioxidant compounds, such as BHT, α-tocopherol, and diphenylamine, the results were in similar ranges. Several extracts showed interesting antifungal activities in the in vitro assays. The extracts obtained with ethyl acetate were the most promising, exhibiting substantial mycelial growth and spore germination inhibition. To validate the antimicrobial efficacy of the extracts demonstrated in vitro, Detached Leaf Assays were optimized for tomato leaves against B. cinerea and for leaves of pear trees against V. pyrina. Results will be compared to commercially available fungicides. In conclusion, olive oil industry by-products have shown to be a promising source of phytosanitary ingredients.

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INHIBITION OF STEEL CORROSION IN HYDROCHLORIC ACID SOLUTION USING CHITOSAN AND CAFFEINE

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caffeine,
corrosion,
chitosan,
inhibitor,
steel

Corrosion, as a process that cannot be stopped, but can be slowed down, is one of the important factors in all branches of industry. The protection of steel against corrosion is especially important, given that steel is the most widely used material in industry, construction, transport, agriculture, shipbuilding, automotive industry, etc. Hydrochloric acid solutions are mostly used in the steel pickling process, but also for the removal of scale from pipelines and plants. Most stainless steels in the environment of a hydrochloric acid solution will corrode because their chromium content is not sufficient to form a protective passive layer. One of the effective ways to protect steel in acid solutions is the application of substances that slow down corrosion, i.e. corrosion inhibitors. Today, as corrosion inhibitors, substances that are environmentally acceptable and which, due to their chemical structure, possess good inhibitory properties are the most tested, and some of these substances are chitosan and caffeine. Chitosan as a natural polymer has a wide range of applications due to its properties of biocompatibility, biodegradability and non-toxicity. Caffeine is a naturally occurring molecule and it is a non-toxic and environmentally-friendly substance found in several foods such as coffee and tea. Therefore, in this work, the inhibition efficiencies of chitosan solutions of different concentrations, as well as caffeine, on steel corrosion in a 10% hydrochloric acid solution was tested. Corrosion rates of steel in HCl solutions without and with tested inhibitors were determined by the gravimetric method at 25°C, 40°C and 60°C. Surface roughness values were determined on the steel samples, while the surfaces of the samples were recorded with an optical metallographic microscope. Chitosan, as well as caffeine, showed very good inhibition properties, reducing the corrosion rate of steel in hydrochloric acid both at room temperature and at an elevated temperature. At room temperature, caffeine proved to be the best inhibitor with a concentration of 1 g/L, where the lowest rate of corrosion action was determined, and the degree of protection was 76.25%. It is interesting that when the temperature rises, the inhibitory effect of caffeine decreases, while on chitosan, elevated temperatures have the opposite effect, the inhibitory effect of chitosan improves.

EVALUATION OF THE ANTIMICROBIAL, ANTIPROLIFERATIVE, AND ANTIOXIDATIVE ACTIVITY OF BLACKCURRANT AND BILBERRY LEAF EXTRACTS OBTAINED BY THE GREEN APPROACH OF ACCELERATED SOLVENT EXTRACTION

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KEYWORDS:
antimicrobial, antiproliferative, antioxidative, blackcurrant, bilberry, leaves

Due to the high content of anthocyanins, the antioxidant properties determined by chemical methods of blackcurrant and bilberry berries are well researched, but studies on the antimicrobial, antiproliferative, and antioxidative activity in cells of the above-mentioned leaves are scarce. Plant leaves are a by-product of berry cultivation, and the presence of flavonols has been confirmed as the predominant compounds in both blackcurrant and bilberry leaves (1). In this study, the antimicrobial properties of blackcurrant and bilberry leaf extracts against Gram-positive and Gram-negative bacteria, lactic acid bacteria, and yeasts were determined using the wall diffusion method, the microdilution method (MIC), and the colony count method. The in vitro biological activity on the human squamous carcinoma (CAL 27) and human hepatocellular carcinoma cell line (HepG2) was evaluated using MTT, DCFH-DA, and clonogenic assays. The extracts of bilberry leaves showed some degree of antimicrobial activity against the Gram-positive target bacteria: S. aureus, B. subtilis, and E. faecium, while blackcurrant leaf extracts were more effective and additionally inhibited the growth of Gram-negative bacteria: S. enterica s. Typhimurium and E. coli. The entire concentration ranges of blueberry leaf extract had no statistically significant effect on the proliferation, ROS levels, or clonogenic growth of CAL 27 and HepG2 cells compared to the negative control. In contrast, the lowest tested concentration (0.014 mg/mL) of blackcurrant leaf extract exhibited statistically significant antioxidant activity in the HepG2 cell line. Furthermore, the two highest tested concentrations (0.5 and 0.2 mg/mL) and the lowest concentration of blackcurrant leaf extract statistically significantly reduced the survival of both tested cell lines. Additionally, a statistically significant dose-dependent inhibitory effect of blackcurrant leaf extract on the clonogenic growth of CAL 27 and HepG2 cells was demonstrated.

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ISOLATION OF PIGMENTS FROM BROWN MACROALGAE *CYSTOSEIRA CORNICULATA, ERICARIA CRINITA* AND *GONGOLARIA BARBATA*

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KEYWORDS:
macroalgae,
Cystoseira,
solid phase extraction,
fucoxanthin,
pigments

Solid-phase extraction (SPE) was performed for the isolation of the pigments from three brown macroalgae: Cystoseira corniculata, Ericaria crinita and Gongolaria barbata from the Adriatic Sea. Four fractions were obtained for each alga; fraction 1 (F1) and fraction 2 (F2) were used to purify the analytes of interest - pigments, which were collected in fractions 3 (F3) and 4 (F4). The obtained fractions F3 and F4 were subjected to high performance liquid chromatography (HPLC) in order to identify and quantify the pigments, and the concentrations of total pigments were determined spectrophotometrically. In all three types of macroalgae, fucoxanthin was recorded as the main pigment in the fraction F3, and chlorophyll a as the main pigment in the fraction F4. Of the total carotenoids, C. corniculata had the highest concentration, amounting to 0.67 mg/g of dry extract. G. barbata contained the most chlorophyll a, in a concentration of 0.80 mg/g dry extract, as well as chlorophyll b: 0.75 mg/g dry extract. For the species C. corniculata, the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method was also carried out, and the antioxidant activity was proven with a DPPH radical inhibition percentage of 80.18% in the fraction F3.

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A SUSTAINABLE APPROACH TO THE DISPOSAL OF MERCURY-SATURATED FeS-DOPED NATURAL ZEOLITE BY SOLIDIFICATION/ STABILIZATION IN A CEMENT MATRIX

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KEYWORDS:
hazardous waste, leaching mechanism, mercury-saturated zeolites, safe disposal, stabilization/ solidification

This study investigates Hg leachability from mercury-saturated FeS-doped natural zeolite (FeSZHg) and its solidified/stabilized form in cement matrix (FeSZHg-Cem). Different doses of FeSZHg of 10%, 20%, 30% and 40% were subjected to solidification/stabilization (S/S) treatment using ordinary Portland cement as binder. Short-term leaching characteristics was assessed by the Toxicity Characteristic Leaching Procedure (TCLP), and long-term by the Dutch dynamic leaching test (NEN 7345). The efficiency of the S/S treatment was evaluated by determining the cumulative Hg release, effective diffusion coefficients (De) and leachability indices (LI). The results of a short-term leaching test from both, granular FeSZHg and ground S/S FeSZHg-Cem specimens showed that the released Hg concentrations were higher than the prescribed TCLP limit value of 0.2 mg Hg/L. The results suggest that the FeSZHg sample represents a hazardous waste and that ground S/S waste should neither be disposed of nor reused. A long-term Dutch leaching test from monolithic S/S specimens showed that the concentration of cumulatively released Hg increased with increasing FeSZHg content as well as De values. The dominant Hg leaching mechanism for the S/S specimen with the addition of 10% FeSZHg is diffusion, whereas for the other S/S specimens it is surface wash off in the initial stages followed by delay diffusion. Leachability index values >19 indicate low Hg mobility from monolithic specimen, confirming that Hg is chemically bound to FeSZ and hydration cement products and physically encapsulated in the cement matrix. Since Croatia, like most EU member states, does not have landfills for S/S hazardous waste and thus no waste acceptance criteria for landfilling, the UK prescribes a leaching limit value for monolithic waste determined according to the NEN 7345 protocol in the leachate up to 0.4 mg/m2. Only the S/S sample supplemented with 10% FeSHg meets this requirement, indicating its harmless long-term environmental risk and can be disposed of at a hazardous landfill. Moreover, the utilization of FeSZHg for special purposes as fillers in concrete structures such as road-based materials seems to be a reasonable method of their safe reuse, which is an imperative of sustainable development.

NATURAL DEEP EUTECTIC SOLVENTS FOR SUSTAINABLE EXTRACTION OF LIGNANS FROM BURDOCK SEEDS

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KEYWORDS:
arctigenin, arctiin, Arctium lappa L., NaDES, seed

Burdock (Arctium lappa L., Asteraceae) is a herbaceous biennial plant widely distributed in temperate regions of Europe and Asia. Apart from its status as a nutritive and healthy food, the burdock enjoys a longstanding use in traditional medicine. In terms of therapeutic potential, burdock roots, leaves and seeds stand out in particular. Burdock seeds have been commonly used for the treatment of sore throat, urinary tract complaints and various dermatological conditions. In addition, they are recognized as promising antidiabetic and anticancer agents. It is believed that the main contributors to these medicinal properties are lignans – arctigenin (aglycone) and arctiin (glycoside). Moreover, it has been suggested that the predominance of one of these two compounds, which is dependent on glycoside stability, significantly influences pharmacological activities. The present work aimed to examine the effect of green solvents, natural deep eutectic solvents (NaDESs), on the extraction of arctigenin and arctiin from burdock seeds, considering their impact on arctiin to arctigenin conversion. Eight different NaDESs, composed of betaine or proline as a hydrogen bond donor, and organic acids (lactic and citric) or polyols (sorbitol and glycerol) as hydrogen bond acceptor, were used for the ultrasound-assisted extraction of arctigenin and arctiin from burdock seeds, and further compared with the conventional solvents (water, 70% ethanol and 70% methanol). Based on the results obtained by the HPLC analysis, two groups of burdock seed extracts were separated – arctiin (betaine/organic acids; proline/organic acids; 70% ethanol and 70% methanol) and arctigenin (betaine/polyols; proline/polyols and water) rich extracts. Proline/lactic acid showed the highest extraction capacity for arctiin (27.8 mg/g dry seed), whereas proline/glycerol mixture proved to be the most efficient extraction solvent for arctigenin (20.4 mg/g dry seed). On the other hand, the amount of analysed lignans was approximately 4-fold lower in extracts prepared with conventional solvents. It seems that the extraction, as well as the transformation of arctiin to arctigenin, could be connected with physicochemical characteristics of the solvent. Overall, these results highlight the potential of NaDESs for obtaining burdock seed extracts with a favourable chemical composition that can be used in the field of the cosmetic or pharmaceutical industry.

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INFLUENCE OF MICROWAVE EXTRACTION PARAMETERS ON THE TOTAL POLYPHENOLS AND ANTIOXIDANT CAPACITY OF BORAGE AND LEMON BALM EXTRACTS

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KEYWORDS:
Anioxidant properties, Borage, Melissa, Microwave-assisted extraction, Total polyphenols

The incorporation of plant extracts into edible coatings and films has gained popularity over the last decade as an efficient means of providing natural bioactives while being part of environmentally friendly packaging solutions. Due to the presence of various bioactive species known for their antimicrobial, antioxidant and antifungal properties, the extracts of Mediterranean plants contribute to the preservation of various foods with a short shelf life, such as fish and meat. Borage (Borago officinalis) and lemon balm (Melissa officinalis) are edible Mediterranean plants with numerous beneficial medicinal effects and properties and are frequently used as herbal medicines. The aim of this work was to optimise the parameters of microwave-assisted extraction (MAE) in terms of total phenolic compounds (TPCs) and antioxidant activities to obtain bioactive extracts of borage and lemon balm for their further use in bio-based formulations of edible coatings for fish preservation. Using water and 30%, 70% and 96% aqueous ethanol solutions as solvents, MAEs were performed at temperatures of 40 °C, 60 °C and 80 °C for 5 minutes. The Folin-Ciocalteau method was used to determine the TPC of the extracts, while their antioxidant capacity was evaluated using DPPH and FRAP assays. In most cases, increasing the MAE temperature resulted in an increased yield of polyphenols in all solvents, and the highest TPC was observed when 30% and 70% aqueous ethanol was used as extraction solvent, namely 1750 and 1331 mg GAE L-1 for lemon balm and 327 and 387 mg GAE L-1 for borage, respectively. According to the results of the DPPH analysis, these lemon balm extracts also showed the highest antioxidant potential at all temperatures, with a range of 88 to 91 % of radical scavenging activity (RSA). The highest RSA, ranging from 82% to 87% depending on the temperature, was found for borage extracted with 70% ethanol. In contrast, the results of FRAP analysis varied at different temperatures depending on the solvent used. The FRAP results showed the highest antioxidant effect for 30% ethanol extracts at 40 °C, for 70% ethanol extracts at 60 °C and for water extracts of lemon balm at 80 °C. The highest FRAP values of borage extracts were: Water at 40°, 30% ethanol at 60° and 80°.

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CHARACTERIZATION OF BIOACTIVE COMPOUNDS IN THE EXTRACT OF THE FRUIT AND LEAF OF *ARBUTUS UNEDO* L. (THE STRAWBERRY TREE)

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KEYWORDS:
Arbutus unedo L., extraction, IR spectroscopy, phenolic compounds, antioxidant activity

Almost all parts of Arbutus unedo L. (the strawberry tree) are used in traditional medicine to treat infections, cardiovascular diseases, hypertension, diabetes and inflammatory diseases, with its antioxidant effect attributed to the plant's polyphenolic profile.1,2 This paper presents the results of studies conducted using extracts from the leaves and fruits of A. unedo collected from various Croatian islands (Vis and Mali Lošinj). Bioactive components were first isolated using different extraction methods (classical, Soxhlet and ultrasonic) with solvents of varying polarity. The obtained extracts were then purified using preparative thin layer-chromatography (PTLC) or column chromatography, and the dominant components were characterised by IR spectroscopy. The recorded spectra showed absorption bands attributed to hydroxyl, ester, and carbonyl groups characteristic of phenolic compounds. The extracts were further analyzed to determine the phenolic compound profile and antioxidant activity. The obtained data were compared to provide insights into the composition of bioactive components based on the location of the collected leaves and fruits of A. unedo.

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ISOLATION OF BIOACTIVE COMPOUNDS FROM VEGETABLE BY-PRODUCTS USING A PULSED ELECTRIC FIELD AS PRE-TREATMENT

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KEYWORDS:
pulsed electric field, lycopene, β-carotene, polyphenolic compounds

Food processing produces large quantitis of wastes (seeds, peel, pulp, fibrous parts). Waste production represents a global problem in economical and enviromental aspects. Food by-products are an excellent source of nutrients and bioactive compounds, so recycling and reusing of these products can reduce processing costs [1]. Carotenoids (β-carotene and lycopene) and polyphenols are the main biologically active compounds in tomato waste. Drying, grinding, extraction and fermentation are well-known waste processing methods. Novel non-thermal technologies such as pulsed electric field (PEF), ultrasonication and supercritical extraction are used for bioactive compounds extraction. PEF treatment increase membrane permeability allowing the molecules to pass undisturbedly into the intercellular space [2]. The total number of bioactive compounds extracted from food waste is increased after PEF treatment. The aim of this work was to investigate the effects of PEF treatment on extraction of carotenoids and polyphenolic compounds from tomato peels. Dried and grinded tomato peels were used for this experiment. HVG60/1 PEF, Impel d.o.o., Croatia was used for PEF-assisted extraction. pH and conductivity were measured using pH 340i/SET, WTW, Germany. Secomam UviLine 9400, Secomam Groupe Aqualabo, France, was used for the determination of antioxidant activity, total carotenoids and polyphenol content. Color determination was investigated using Spectroquant Prove 300, Merck Darmstadt, Germany. Lycopene and β-carotene content were evaluated using HPLC, Agilent Technologies, SAD. The electrical conductivity, color determination, antioxidant activity and bioactive compound composition in the treated food waste depend on the duration of PEF treatment and the applied voltage. A higher electrical conductivity of the samples was correlated with a higher polyphenolic content. Sample color was associated with the content of extracted bioactive compound in obtained extracts. PEF assisted extraction results in higher lycopene and β-carotene content, which causes a lighter or darker color of the sample. Usage of a higher electrical voltage in the treatment leads to an improvement in antioxidant activity in all treated by-products. The positive impact of PEF-assisted extraction was also confirmed by the increase in total polyphenol content. Our results indicate that PEF treatment provides better benefits for extraction compared to conventional extraction.

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ACTIVATED SAWDUST DERIVED BIOCHAR FOR ADSORPTION OF DYES

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KEYWORDS:
adsorption, biochars, sawdust

Biochar is a low-cost and environmentally friendly carbon material with large specific surface area and rich surface functional groups. As such it has attracted extensive attention for environmental applications: as a good sorbent in carbon capture, storage processes in industrial settings and for diverse organic or inorganic pollutants adsorption. The adsorption of Acid Yellow 23 (AY23) was investigated using obtained activated biochars, which were produced of activated carbonized. Dry sawdust of Turkish oak (Quercus cerris) was activated with H_3PO_4, KOH, and H_2O_2 in three different mass ratios of activator to sawdust (1:1; 2:1; 4:1) for 1h at 50°C. The untreated sawdust and activated samples were carbonized at 400°C for 60 minutes in air-limited conditions, resulting in 10 biochar samples. After carbonization, the samples were washed to neutral pH and dried overnight at 60°C. All produced biochars were tested as adsorbents for textile dye Acid Yellow 23 (AY23) at 25°C for 24 h. The UV-VIS spectroscopy was applied to monitor the concentration of AY23 during the adsorption process at λmax=426 nm. The adsorption results revealed that activation with KOH and H2O2 didn't show significant improvement of adsorption properties. On the other hand, activation using H3PO4 in a mass ratio of 4:1 (CP14) demonstrates a significant improvement in adsorption properties, with a 67% enhancement in dye removal. Activation using lower mass ratios (1:1 and 2:1) did not improved adsorption properties. The adsorbent CP14 is characterized by low-temperature N2-physisorption, where it was found that the specific surface area of the adsorbent is 859.3 m^2g^{-1}.

THE ROLE OF DEEP EUTECTIC SOLVENTS IN ENHANCING SUSTAINABILITY AND EFFICIENCY IN BIOCATALYTIC PROCESSES

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KEYWORDS: *biocatalysis, CO_2 conversion, dehydrogenases, DESs, furfurylamine*

The biocatalytic transformation of CO_2 and furfural into valuable products offers a sustainable solution to reducing carbon emissions and reliance on non-renewable feedstocks. Using enzymes, this green process efficiently converts these abundant resources into high-value compounds, supporting environmental and economic sustainability. However, challenges like low CO_2 and furfural solubility and enzyme/cofactor instability in water limit the efficiency of these biocatalytic processes. To overcome these limitations, Deep Eutectic Solvents (DESs) have been explored as a potential solution. DESs present a promising alternative to conventional solvents in biocatalysis due to their non-volatility, non-flammability, and tunable properties. They enhance enzyme solubility, stability, and in some cases, activity, making them ideal for environmentally friendly processes. By addressing issues such as low substrate solubility and enzyme denaturation, DESs improve the efficiency of biocatalytic reactions. These solvents can also serve as an effective medium for enzyme storage, preserving enzyme activity over time. Additionally, DESs can facilitate the removal of byproducts, thereby maintaining the efficiency and purity of the desired products. This multifunctional capability allows DESs to complement and optimize biocatalytic processes, offering benefits that extend beyond those provided by conventional solvents and buffers. However, careful selection and design of DESs, considering factors like toxicity and enzyme compatibility, are crucial for maximizing their effectiveness in sustainable production.
Here, we present our extensive work in biocatalysis using DESs, focusing on dehydrogenases-catalysed CO_2 reduction to formate and transaminase-catalysed amination of furfural to furfurylamine. For CO_2 conversion reaction we utilized Quantitative Structure-Activity Relationship (QSAR) models to predict enzyme behavior and streamline the complex process of DES selection: through a combination of experimental screening and computational tools, we demonstrate this approach by optimizing DES for CO_2 reduction. In the context of furfurylamine production from furfural, DESs were used in downstream processing for removal of acetophenone, a byproduct of the reaction that can interfere with further applications of furfurylamine, particularly in pharmaceutical and polymer synthesis.

GENETIC MODIFICATION OF NON-CONVENTIONAL YEAST Scheffersomyces stipitis FOR LACTATE PRODUCTION

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KEYWORDS:
L-lactate, bioplastics, non-conventional yeasts, Scheffersomyces stipitis

Considering the widespread plastic pollution on land and in the oceans, it is increasingly important to use biodegradable plastics in processes where the use of plastic is unavoidable. One widely used example of biodegradable plastic is polylactic acid (PLA), the production of which is not based on fossil fuel processing but on biotechnological production from renewable resources. The basic monomer in the production of PLA is L-lactic acid, which is also widely utilised in the food, chemical, and pharmaceutical industries. Optically pure L- and D-lactate can be produced biotechnologically, by utilising microbial L- or D-lactate dehydrogenases. The main advantage of microbial production of lactate compared to chemical synthesis is the simplicity of the process and the possibility of producing an optically pure product that is significantly more valuable and applicable than the racemate. The non-conventional yeast Scheffersomyces stipitis, which can efficiently ferment both hexoses and pentoses, is a promising candidate for sustainable production of various biochemicals from renewable lignocellulosic materials. Although this yeast does not naturally produce lactic acid, it is an interesting candidate for industrial production due to its intrinsic tolerance to low pH values as well as to other process conditions. We constructed a strain that expresses two codon-optimized L-lactate dehydrogenases derived from Lactobacillus gasseri. Using the newly constructed strain, we achieved lactate production on both glucose and xylose. Increased yield of lactate from glucose was achieved by the addition of the neutralizing agent $CaCO_3$ during fermentation, which additionally inhibited lactate degradation by S. stipitis after exhaustion of other carbon sources. Furthermore, by raising the temperature to 37 °C, the engineered strain achieved a higher yield of L-lactate from glucose compared to experiments conducted at 28 °C. It is also important to emphasize that this modified strain did not produce ethanol during the fermentation of xylose into lactate as opposed to the wild strain.

POLYPHENOL AND PROTEIN CONTENT IN WILD THYME DUST EXTRACTS WITH NATURAL DEEP EUTECTIC SOLVENTS

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KEYWORDS:
dust, NADES, polyphenol, protein, Thymus serpyllum L.

Natural deep eutectic solvents (NADESs) are a green and nontoxic alternative to potentially toxic organic extraction mediums. Wild thyme (Thymus serpyllum L.) contains a wide range of bioactive compounds that have an important role in its antioxidant, antimicrobial, carminative, expectorant, analgesic, stimulant, diaphoretic, antispasmodic, diuretic, and anti-inflammatory effects. The aim of this study was to evaluate wild thyme dust in terms of polyphenol and protein content. Wild thyme dust was from the Institute for Medicinal Plants Research "Dr Josif Pančić", Pančevo, Serbia. The extraction was performed at room temperature in the incubator shaker KS 4000i control (IKA, Germany) using four different NADESs (citric acid/glucose, citric acid/saccharose, malic acid/glucose, and malic acid/sacharose with 50% of water) and a solvent-to-solid ratio of 30:1 mL/g for 75 min. Total polyphenol and protein content were measured employing spectrophotometric methods. Polyphenol concentration varied from 28.6 to 45.1 mg gallic acid equivalent/g of plant material, while protein content was in a range of 21.4 to 25.5 mg of albumin equivalent/g of plant material. In both measured parameters, the efficiency of the employed NADESs follows the trend: citric acid/saccharose≥citric acid/glucose>malic acid/sacharose≥malic acid/glucose. Wild thyme dust extract prepared using citric acid/saccharose in comparison to other tested NADESs was favored as a potential ingredient in foods, functional foods, dietetic supplements, or pharmaceuticals.

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BIOSORPTION POTENTIAL OF BUCKWHEAT HULLS BIOCHAR FUNCTIONALIZED WITH H_2SO_4 AND $FeCl_3$ FOR PHOSPHATE REMOVAL FROM WASTEWATER

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KEYWORDS:
biochar, biosorption, buckwheat hulls, phosphates, wastewater

Phosphates are often present as nutrients in wastewater in considerable quantities, which can lead to ecological problems such as eutrophication. Their presence in water bodies in higher than permissible concentrations can also lead to a decrease in oxygen levels in the water, which endangers the life of aquatic organisms and disturbs the ecological balance. The removal of phosphates from wastewater helps to maintain the quality of natural water bodies and thus ensuring the health of aquatic organisms and safety for possible human use. The aim of the work was to investigate the possibility of phosphate removal from model solutions and synthetic wastewater using biochar from buckwheat hulls (roasted at 220°C) functionalized with H_2SO_4 and $FeCl_3$. To this end, batch experiments were conducted in which the efficiency of biosorption was tested as a function of the concentration of the biosorbent (1 - 10 g dm^{-3}), the contact time (15 - 360 minutes), the initial phosphate concentration (1 - 300 mg dm^{-3}) and the pH (2 - 10). In addition, desorption tests were carried out with different solvents. Higher concentrations of biosorbent decreased the amount of adsorbed phosphate per unit mass and increased the overall percentage of phosphate removal. Higher initial phosphate concentrations resulted in more adsorbed phosphate per unit mass. The most efficient solvent for phosphate desorption was 0.1 M HCl, however, the overall percentage of phosphate desorption was low (6%). Phosphate biosorption was less effective in synthetic wastewater than in phosphate model solutions.

KINETIC MODELING OF *RALSTONIA EUTROPHA* H16 GROWTH ON DIFFERENT MEDIA

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KEYWORDS:
biohydrogen, Ralstonia eutropha, hydrogenases, kinetic parameters, mathematical modeling

Due to environmental pollution and the depletion of fossil fuels, there is growing interest in the development and use of biofuels as environmentally friendly alternatives. Biofuels offer a promising solution to reduce harmful greenhouse gas emissions and stabilize energy costs worldwide. Among the most promising biofuels is biohydrogen, a hydrogen produced through sustainable processes using microorganisms such as bacteria and algae. One of the most interesting bacteria for hydrogen production is Ralstonia eutropha H16, known for its ability to produce oxygen-tolerant hydrogenases. These enzymes play a crucial role in biohydrogen metabolism and production.
The aim of this work was to cultivate R. eutropha H16 in a batch reactor using different synthetic media with different concentrations of fructose and glycerol. The biomass and substrate concentrations were monitored throughout the cultivation process in order to collect the necessary data for estimating the kinetic parameters of the process. The mathematical model, composed of the growth kinetics and the corresponding mass balances, was developed. In the next step, the model was validated using two independent experiments with different initial substrate concentrations. In order to propose the best cultivation process, the mathematical model was developed for different reactor types (batch, fed batch, continuous stirred-tank reactors, etc.). In the final step, based on the results obtained by the mathematical model siimulations, the cultivation of R. eutropha H16 was carried out in the most efficient reactor and under optimal initial substrate concentration.

EXPLORING THE POTENTIAL OF PANNONIAN THYME (*Thymus pannonicus* ALL.): SUPERCRITICAL CO2 EXTRACTION FOR THE RECOVERY OF LOW POLAR FRACTION

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KEYWORDS:
Thymus pannonicus, Supercritical carbon dioxide extraction, enzymatic pre-treatment, microwave pre-treatment, Gas chromatography

Due to the broad spectrum of biologically active compounds, plants within the Thymus genus were used, since ancient times, as remedies for a number of different illnesses. While many species like Spanish thyme or Common thyme are well known and described thanks to their antimicrobial, anti-inflammatory, diuretic, or antiseptic activity, Thymus pannonicus All. (Pannonian thyme) however, remains relatively unexplored, despite its unique characteristics. Spread over central and eastern Europe, Pannonian thyme is a small shrub, with diverse chemical composition which is mostly location depended. Within this study, citral chemotype of Pannonian thyme was used, that up to our knowledge was found and described only in northern Serbia. Therefore, supercritical carbon dioxide ($ScCO_2$) extraction followed by GC-MS analysis was applied to explore composition of bioactive components of T. pannonicus low polar fraction. Different $ScCO_2$ extraction pressures were tested (100, 150, 200, 250, and 300 bar), and two different plant material pre-treatments (enzymatic and microwave) in order to maximize the extraction yield and to determine the influence of different extraction pressures on the chemical composition of the extract. For the untreated T. pannonicus plant material the highest yield of low polar extract was 3.01% (w/w) and it was obtained at conditions of 150 bar and 40 °C. At the same extraction conditions application of 4% (v/w) enzymatic pre-treatment increased extraction efficiency, and provided yield of 3.89% (w/w). GC-MS analysis was conducted for all of the obtained extracts, and the results indicated that oxygenated monoterpenes and sesquiterpenes were two most dominant groups of bioactive components, with highest concentrations of (E)-citral (18.95 – 38.17%), (Z)-citral (6.68 – 14.66%), β-bisabolene (8.2 – 14.4%), and nerol (6.08 – 9.67%).

NOVEL APPROACH TO OLIVE FRUIT FLY (*BACTROCERA OLEAE*, ROSSI) MONITORING AND/OR CONTROL USING VOLATILE COMPOUNDS PRODUCED BY BREWING BY-PRODUCT

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KEYWORDS:
entomology, fruit flies, non-pesticidal control, olive, sustainable pest management

The olive fruit fly (Bactrocera oleae Rossi) is the most economically important olive pest, and its presence regularly has a negative impact on the quantity and quality of olive fruit and oil. For years, the control of B. oleae was based exclusively on pesticides, which have had a negative impact on the environment and biodiversity in olive groves in recent decades. The EU has therefore set itself the target of reducing the use of pesticides by 50 % by 2030 and 100 % by 2050. Effective non-pesticidal methods to monitor and/or control B. oleae are needed to sustainably reduce the damage by reducing the use of conventional insecticides. Current evidence suggests that various waste brewer's yeasts (WBY) attract certain teprhitids, but it has not yet been investigated which of the volatiles they produce attract a particular pest species. The interaction between B. oleae and WBY, a by-product of beer production, and their volatiles has not yet been investigated. The aim of the study is therefore to investigate whether two types of modified WBYs are attractive to B. oleae and, if so, which volatiles might be responsible for the attraction. For this reason, two types of WBYs (Ale - Saccharomyces cerevisiae and Lager - S. pastorianus) were procured from two Croatian beer producers for the production of protein baits to be used for further investigations. Both WBYs were modified in the laboratory by boiling in a water bath with constant stirring. After boiling, the concentrated yeasts were digested with papain and preserved with methyl p-hydrozybenzoate and refrigerated at 4°C. The volatile compounds were identified by HS-SPME-GC/MS. Thirty-nine volatiles were identified in WBY from ale beer production, while 31 volatile compounds were identified in WBY from lager beer production. The most common volatiles identified in ale WBY were ethyl octanoate, ethyl decanoate and β-myrcene, while ethyl decanoate, ethyl octanoate and ethanol were found in lager WBY. The attraction of B. oleae to both modified WBYs will be tested in laboratory and field trials, and the most promising volatiles responsible for the attraction of B. oleae to both modified WBYs will be determined based on laboratory and field trials. Among these, five volatile blends will be selected for further investigation. A more comprehensive knowledge of the effects of both protein-based baits and their volatile compounds on the behavior of B. oleae could improve the use of attractants as baits for insect control.

RECENT ADVANCES IN PLANTS EXTRACTS AS GREEN CORROSION INHIBITORS FOR CARBON STEEL IN AGGRESSIVE SOLUTIONS

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KEYWORDS:
plant extracts, carbon steel, corrosion inhibition, green corrosion inhibitors, green chemistry

Carbon steel, independently on its carbon content, has been proven to be one of the most used metals in different industries. However, carbon steel is highly susceptible to corrosion in a wide range of environments, including acidic, basic and chloride-containing solutions. This study presents the progress made on the last five years on the use of plant extracts as an environmentally friendly alternative to mitigate corrosion of different types of steel (mainly carbon steel and stainless steel) exposed to aggressive environments. The advantages and disadvantages of using plant extracts as corrosion inhibitors in general will be critically presented, focusing on the sustainability of the extract preparation and characterization procedures, including the role of solvents, type and part of the plant extracted, on the corrosion inhibition effectiveness of the obtained extracts. In addition, the general corrosion inhibition mechanism as well as the high temperature and long-term corrosion inhibition performance of these extracts will be discussed. Finally, possible future improvements in this area, including the use of corrosion inhibition formulations will be presented.

ULTRASOUND-ASSISTED NATURAL DEEP EUTECTIC SOLVENTS EXTRACTION OF BIOACTIVE COMPOUNDS FROM ROSEHIP FRUITS

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KEYWORDS:
NaDES, Rosa canina L., rosehip fruits, total carotenoids, total phenolics

Wild rose (Rosa canina L.) is a deciduous shrub belonging to the family Rosaceae, which represents a source of fruits with special nutritive and medicinal value. Numerous phytochemical analyses have reported that rosehip fruits are rich in ascorbic acid and carotenoids, along with different groups of polyphenols. Due to such a unique chemical composition, rosehip fruits are used as traditional herbal medicine in the treatment of colds and chills, for the alleviation of pain and joint stiffness related to osteoarthritis, as well as in skin care. Bearing in mind the growing emphasis on environmental and economic sustainability, green extraction techniques have become significant for obtaining extracts with favourable characteristics. The aim of this study was to evaluate the impact of natural deep eutectic solvents (NaDESs) and 70% ethanol as conventional solvent on the ultrasound-assisted extraction of total phenolics and total carotenoids from rosehip fruits (Rosae pseudo-fructus). After screening analysis, in which six NaDESs (betaine/citric acid; betaine/malic acid; citric acid/sucrose; malic acid/sucrose; citric acid/glycerol; malic acid/glycerol) were evaluated, NaDES composed of betaine and citric acid at a molar ratio of 1:1 was selected as the most promising for the simultaneous extraction of total phenolics and total carotenoids, in addition to the greatest antioxidant activity. The optimal extraction conditions, established by the Box-Behnken design coupled with response surface methodology, were found to be 50.0% (w/w) water in NaDES, an amplitude of 43.1% and extraction time of 11.6 min, under which the extraction yield for total phenolics was 125.0 mg/g and for total carotenoids 247.3 μg/g of dry rosehip fruits, exceeding the amount of total phenolics (49.6 mg/g) and total carotenoids (49.9 μg/g) determined in the case of 70% ethanol. These results point out that betaine/citric acid NaDES allowed efficient extraction of bioactive compounds from rosehip fruits, whereas the obtained extract holds a great potential for incorporation into natural-based products.

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ASSESSMENT OF THE ENERGY POTENTIAL OF FLAX AND HEMP BY-PRODUCTS

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KEYWORDS:
flax, hemp, energy potential, torrefaction, high heating value

Rapid urbanization and population growth contribute significantly to the increase in food waste. In economic terms, food waste causes considerable losses in all segments of the food supply chain. From an environmental perspective, it leads to an increase in greenhouse gas emissions both during decomposition and production. In the food industry, efforts are being made to minimize waste by optimizing production processes and recycling the inedible parts of food waste.

Hemp seeds used to produce hemp oil leave behind a hemp oil cake as a solid residue from the oil extraction process. This cake is rich in minerals, vitamins, fibre and unsaturated fatty acids and is therefore suitable as animal feed and for energy use. Flax, one of the oldest cultivated plants, is mainly used for fibre weaving and the extraction of linseed oil. Its oil cake is also rich in fibre and has a high energy value. There is considerable potential for diversified utilisation of oil cakes. However, long-term storage of oil cakes is problematic due to possible microbiological contamination by mold, bacteria and fungi, especially under humid conditions. Overcoming such challenges and researching new applications can lead to more sustainable and economically viable utilisation.

Torrefaction is a promising solution for improving the storage and energy potential of these by-products. In this thermochemical process, the material is heated in an inert atmosphere at moderate temperatures, usually between 200 and 450 °C, which leads to significant changes in the chemical composition and properties of the material. By fine-tuning the temperature and exposure time, the process can improve the energy value, stability and carbon content of the material and reduce its volatile components.

This research focuses on the evaluation of the efficiency of the torrefaction process for hemp and flax oil cake. The study uses thermogravimetric analysis, higher heating value determination and FTIR spectroscopy to analyse the energy potential of torrefied by-products from the vegetable oil industry.

Session D:

URBAN FOREST AND URBAN GREENING

MODELING FOR OPTIMAL TREE SPECIES SELECTION CONSIDERING AIR POLLUTION REMOVAL CAPACITY IN URBAN ECOSYSTEMS -FLORTREE-

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KEYWORDS:
Air quality, Ecosystem services, Ornamental trees, Tree selection, Urban greening

Atmospheric pollution, mainly caused by urbanization, is a threatening problem around the world especially in industrialized countries such as Europe and Asia. Among atmospheric pollutants, tropospheric ozone (O_3), nitrogen dioxide (NO_2) and particulate matter (PM2.5 and PM10), are the most dangerous affecting citizens' health. Urban trees can reduce the air concentrations of these pollutants thanks to stomatal uptaking and allowing dry deposition on their canopies. On the other hand, some species emit hydrocarbons (VOCs) such as isoprene and monoterpene that are O_3-precursors leading to air quality deterioration. For this reason, within AIRFRESH project (LIFE19 ENV/FR/000086), we developed FlorTree an innovative single-tree model to estimate the flux of air pollutants and select the best species for urban greening. FlorTree considers species-specific parameters such as tree morphology (height and crown leaf area), leaf/shoot structure, leaf habit (deciduous or evergreen) and physiological responses (stomatal conductance and VOCs emissions) to environmental factors. Hourly concentration data for air pollutants (O_3, NO_2, and PM10) and meteorological parameters (temperature, solar radiation, relative humidity and wind speed) were recorded during one-year of observations and used as model input. In this study we compared the urban trees' removal capability in cities characterized by different pollution situations: two European (Florence, Italy and Bucharest, Romania) and an Asian one (Tokyo, Japan).

OVERVIEW OF PLANT TYPES FOR EXTENSIVE GREEN ROOFS

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KEYWORDS:
biodiversity, extensive green roofs, green and blue infrastructure, implementation

This paper reviews the theoretical principles and applied systems of green roofs, focusing on the methods used to implement different components. With increasing urban interest in sustainable solutions, communities are turning to green roofs to mitigate climate change effects. As part of the Nature-Based Solutions (NBS) initiative, green roofs offer adaptable, sustainable urban infrastructure solutions. Implementing a green roof system is complex and site-specific, requiring clear guidelines to ensure optimal conditions for plant species selection. An overview of plant species suitable for extensive green roofs would facilitate the use of native species, enhancing sustainability. Several factors influence the success of green roof systems, including location, vegetation choice, substrate depth, and the roof's purpose. Green roofs effectively address urban problems like the urban heat island effect, sustainable drainage, and biodiversity enhancement. Their impact on blue and green infrastructure is crucial for climate change mitigation. Local climatic parameters—such as sun exposure, wind, temperature fluctuations, and precipitation—are essential for selecting the appropriate green roof system, substrate thickness, and plant species. Properly selected vegetation is crucial for a successful green roof, especially native species that are better adapted to local climates, reducing the need for maintenance, irrigation, and feeding. Native vegetation also enhances biodiversity and ecological resilience. The depth and composition of the substrate must be compatible with plant species, influencing the vegetation coverage of the green roof. Sustainability can be integrated into green roofs by using recycled materials for substrates, supporting ecological goals and improving biodiversity. Green roofs offer multiple functions beyond biodiversity, including stormwater management, thermal insulation, energy efficiency, and visual enhancement. These functions help determine the specific design, suitable vegetation, and other components like irrigation and substrates. Extensive green roof systems are gaining popularity within NBS initiatives due to their versatility and adaptability. The trend is towards increasing the self-sufficiency of green roofs by integrating green and blue roofs within the same system. This involves creating biodiverse green roofs that accumulate and utilize rainwater and/or grey water on-site. These advancements support the ecological significance of green roofs and enhance their role in urban sustainability efforts.

SUSTAINABLE MANAGEMENT OF EXISTING URBAN TREES BY IMPACT OF SOIL IMPROVEMENT APPLIED TO ROOT SYSTEMS ON TREES VITALITY - research findings

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KEYWORDS:
Soil-improvement, Tree-vitality, Tree-revitalization, Microbiome-revitalization, Sustainable-tree-management

The increasing pollution of water, air and soil, climate change and the associated occurrence of weather events, diseases and pests have a negative effect on the sustainability of urban trees. This is why experts from urban forestry and other professions are trying to find solutions to these problems through new research and innovations focused on natural based solutions and the UN's sustainable development goals. The presentation shows the results of the application of the innovative soil improver Herbafertil on a condition of 56 low vitality spruce trees. The research methodology encompasses: Tree inspections, during which the dimensions of the trees were measured, the health status assessed, and the static safety evaluated using appropriate arboricultural methodologies (VTA, SIA, REZI, TRAQ). The first inspection in Spring 2023., carried out immediately after the installation of soil improver, shows the health status of all trees before the active substances act on the roots or the vitality of the trees. The second inspection was carried out in November 2023. The third inspection was in the spring of 2024. The assessment of vitality and health status of each tree included in the research using the VTA method (Visual Tree Assessment, Matthek and Breloer 1993 - adapted by Pernek et al. 2013) involves an integrated tree diagnosis based on tree biology, symptoms of damage to individual organs, and an assessment of the overall tree vitality. In the initial findings of this research (Spring 2024.), we discuss the spruce as the most common tree species, but also the most endangered species separately, as well as a species that, given the problem of the appearance of the bark beetle (Ips typographus L. (Coleoptera, Curculionidae, Scolytinae), mostly needs to strengthen vitality, and thus resistance to the dangerous pests. The research shows encouraging results and point to the fact that the influence of soil improvers applied to the root systems has a significant effect on tree vitality. 55% of the trees show already an improvement in vitality. Thirteen trees show a significant improvement in vitality, which represents almost 23% of the trees, and an additional eighteen trees, or 32%, show signs of recovery in the form of greening or strong shoot growth. Twenty-two spruces or 38% of the trees show an improvement in vitality, while 7% of the trees have weakened. The causes of weakening can be different and are not necessarily related to the influence of soil improver.

THE BIO-BAT PROJECT: ASSESSING BAT DIVERSITY IN CENTRAL ITALY URBAN-RURAL INTERFACE

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KEYWORDS:
Biodiversity conservation, Chiroptera, green areas, urban forests, urbanization

Urban forests and green areas provide essential habitats to bats, offering roosting sites, foraging opportunities, and corridors for movement, contributing to their survival and population health. These green spaces play a crucial role in mitigating the negative impacts of urbanization on bat populations, such as habitat loss, fragmentation, and disturbance, promoting their long-term persistence in urban environments. Within the BIO-BAT Project, we investigated the bat diversity within the municipalities of Calenzano and Sesto Fiorentino, in the northern part of the metropolitan area of Firenze (Central Italy) between November 2023 and October 2024, in direct continuity with two protected areas (Monte Morello and Calvana Mountains). Using Audiomoth acoustic recorders, the research aimed at identifying bat species, assess their activity patterns, and evaluate their distribution across habitats, including forests, agricultural areas, urban zones, and industrial sites. A total of 596 recordings from 17 sites were analyzed, revealing the presence of 13 bat species, representing a significant portion of Italy's bat fauna. Notably, several species of conservation concern under the Annex II of the Habitats Directive, such as the Geoffrey's bat (*Myotis emarginatus*) and the greater horseshoe bat (*Rhinolophus ferrumequinum*), were detected in the Calenzano municipality. The commonest species were the Savi's pipistrelle (Hypsugo savii) and the Kuhl's pipistrelle (*Pipistrellus kuhlii*), which are well-known urban exploiters. Additionally, species more typical of natural and forest habitats, such as the common noctule (*Nyctalus noctula*), Leisler's bat (*Nyctalus leisleri*), and Daubenton's bat (*Myotis daubentoni*), were recorded. A comparative analysis with the neighboring municipality of Sesto Fiorentino revealed a lower bat diversity, with a predominance of species adapted to human-modified environments. These findings highlight the importance of urban green spaces and forests as refuges for bats and emphasize the role of bats as valuable bioindicators of environmental health. The study underscores the need for continued bat monitoring and conservation efforts, particularly in light of the global decline of bat populations. By understanding the distribution and habitat requirements of bat species, we can develop effective greening strategies to protect these essential components of our ecosystems.

PUBLIC INVOLVEMENT IN PLANNING, MANAGEMENT AND MAINTENANCE OF TREES, FORESTS AND GREEN SPACE IN URBAN AREAS – ATTITUDES OF PROFESSIONALS IN 10 EUROPEAN COUNTRIES

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A survey with 582 professionals dealing with various aspects of planning, management and maintenance related to trees, forests and green space in urban areas was conducted in 10 European coutries. The goal was to explore i) what experiences professionals had with public involvement, ii) what attitudes professionals had towards public involvement in various activities related to trees, forests and green space in urban areas, iii) how they perceive potential advantages and challenges of public involvement, iv) what traits they would expect from potential volunteers, and v) the influence of sociodemographic characteristics of respondents on their attitudes. The results showed, among other, that professionals highly support activities such as monitoring of incivilities, raising awareness and campaigning or litter picking. On the other hand, participation in tree assessment, monitoring of tree pests, diseases and invasive alien species, as well as tree inventorieis were the least supported. Some sociodemographic varibles proved pertinent for professionals' attitudes towards public involvement. Further and in-depth studies are needed for more detailed interpretation of professionals' attitudes and differences among countries.

INFORMED, AWARE AND COMMUNICATIVE YOUNG CITIZENS: A STRATEGIC APPROACH TO ADDRESS URBAN GREENING CHALLENGES

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KEYWORDS:
Urban Greening, Collaborative Community, School engagement, Active citizenship

FuCIn (Future Citizens Involved through European Green Deal EGD challenge - A great fabric of our citizenship – https://fucin-erasmusplus.eu) is an ERASMUS+ project started in October 2024. Its aim is to promote active citizenship by facilitating collaboration among students (Marco Polo and K12 high School), local policymakers (Calenzano and Marmara Municipality) and research institutes (CNR-IBE, INAK and Bilimce Derneği association), with the shared objective of improving and communicating sustainable and green local policies within the framework of the European Green Deal (EGD). To achieve this goal, FUCIN adopts a collaborative and participatory methodology to engage and develop a constructive dialogue between young citizens and institutions. By focusing on STEAM (Science, Technology, Engineering, Arts and Mathematics) topics, the project aims to empower students to take a leading role in decision-making regarding environmental and sustainability policies. Students will be encouraged to develop innovative solutions for environmental challenges, create strategies to raise awareness and share experiences for a green inclusive transformation. Supporting intergenerational dialogue, lifelong non-formal learning and students-municipalities exchanges on urban green management for climate challenges represent a new awareness of sustainable growth, EGD and environmental issues. This strategy builds a dynamic community. The FuCIn approach is innovative because, until now, operational collaboration has been limited to interactions between municipality and academic institutions, middle and high school students participating solely as learners. Fucin breaks new ground by involving students as active contributors in the development and communication of urban green policies. The key steps in this process will be:

-Participative community development between students and municipality to define a framework for raising the awareness of local and EU urban green practices

- Enhancing skills to address Green New Deal and STEAM challenges

- Co-designing ddigital immersive solutions with students and municipalities to disseminate green practices across the EU. FuCIn enhances civic awareness and engagement while strengthening collaboration among schools, municipalities, research institutions and various institutions. By integrating efforts, the project deepens understanding of environmental challenges on both local and global scales, paving the way for a more sustainable and unified future where actions and policies align with shared goals for green and inclusive growth.

SULFUR ACCUMULATION IN FOLIAGE AND SHOOTS OF SMALL LEAVED LINDEN URBAN TREES GROWING NEAR SULFUR THERMAL MINERAL WATER SPRINGS IN TOWN OF VARAZDINSKE TOPLICE, CROATIA

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KEYWORDS:
urban trees,
leaf,
wood,
sulfur,
CHNS analyzer

Sulfur is an essential element for the nutrition and development of plants and is found in the soil in various forms from different sources. Trees in an urban environment can reduce the concentration of sulfur through uptake and deposition in their tissues. The efficiency of sulfur absorption from the soil and deposition in plant tissues varies from species to species, with some species being known as more proficient accumulators compared to others. This study aimed to establish sulfur concentration thresholds in different parts of urban trees based on their proximity to a known sulfur source in the soil and various tree management practices.

The research was conducted in Varazdinske Toplice, Croatia, a town renowned for its sulfur-rich hot springs used in the oldest thermal spas in the country. Sampling took place mid-growing season on nine small-leaved linden trees (*Tilia cordata* Mill.), selected for their proximity to the hot sulfur springs and different tree management history, including both pollarded and naturally developed trees. Samples were taken from the lower to mid-canopy on opposite sides, focusing on branches with current and previous year's shoots and fully matured leaves.

Sulfur concentrations in the shoots and leaf samples were determined using the dry combustion method on a CHNS elemental analyzer in the Forest Biomass Laboratory at the University of Zagreb Faculty of Forestry and Wood Technology.

The results showed different sulfur concentrations in wood and leaf samples from small-leaved linden urban trees. The highest sulfur concentrations were found in the leaves of pollarded trees, while shoots of naturally grown and pollarded trees had the lowest sulfur concentrations. The distance of the trees from the source of known sulfur-containing thermal springs had no effect on the sulfur concentrations in the leaves, but showed a trend of higher sulfur concentrations in the shoots of trees closer to the sulfur source. These findings suggest a greater influence of tree management practice on sulfur uptake and distribution in urban small-leaved linden trees.

Session E:

SUSTAINABLE WOOD PRODUCTS

DESIGN OF A NOVEL PROCESS FOR BIOMETHANE PRODUCTION VIA THERMOCHEMICAL CONVERSION OF WOODY BIOMASS

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KEYWORDS:
Biomass valorization,
Process design,
Gasification,
Syngas upgrading,
Bio-methanation

Biogas production is an effective solution to protect the environment by recycling organic waste streams into renewable energy and products for soil improvement. Moreover, biogas can potentially reduce by 240% the Greenhouse Gases (GHG) emissions compared to EU fossil fuels [1]. However, multiple challenges need to be addressed to make biomethane a viable alternative on the market. In particular, feedstock diversification is a key opportunity to make biomethane production sustainable and profitable in different geographical contexts. Indeed, diversifying feedstock sources can increase biomass availability, address waste management challenges, and enhance the circular economy. In this context, a promising alternative source to anaerobic digestion is the valorization of lignocellulosic biomass, which is characterized by a high energy potential [2]. This work, which is part of the EU-funded SEMPRE-BIO project [3], deals with process design, modelling, and evaluation of key performance indicators for a novel biomethane ecosystem based on microorganism-driven methanation, namely the upgrading of syngas obtained through lignocellulosic biomass gasification. The block flow diagram (BFD) is drawn in Fig. 1. 150 kg/h of woody chips are treated in a gasification chamber, producing 180 Nm³/h of syngas. The gasification process is autothermal since the temperature is maintained constant by recycling and burning 1/3 of the produced syngas. The remaining syngas flow is conveyed to bio-methanation, where an extra hydrogen flow is added to reach 98.5% conversion of the limiting reactant (i.e., CO_2). Finally, the biomethane is cooled down to remove humidity, compressed, and collected for end-use.

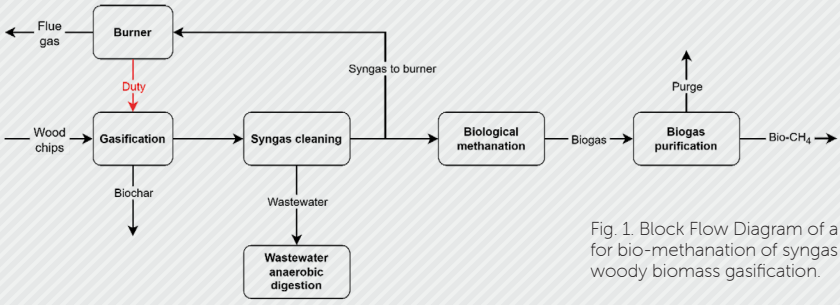

Fig. 1. Block Flow Diagram of a novel process for bio-methanation of syngas generated via woody biomass gasification.

The process is simulated in COCO-COFE v3.6, a Computer-Aided Process Engineering (CAPE) compliant license-free simulation software developed by AmsterCHEM. The gasification chamber is modelled as a Gibbs reactor, including biomass decomposition into light gases, tar, and char, as well as gas phase secondary reforming reactions [4]. The bio-methanation reactor is modelled using a conversion-based soft model published by Li et al. [5]. Mass and energy balances from the model are used to quantify the Key Performance Indicators (KPIs) of the process. Results show that each kg of treated woody biomass yields 0.46 kg of biomethane, with a purity of 96.5 vol%. The external hydrogen demand is 0.1 kg/kg dry biomass. The overall electricity consumption is 0.574 MJ/kg dry biomass. Results from this preliminary study will be used as a basis to perform an economic and envirommental assessment.

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Webpage - SEMPRE-BIO: Innovative Biomethane Production

PROPERTIES OF WOOD LAMINATED COMPOSITES BONDED WITH CITRIC ACID-BASED ADHESIVE

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KEYWORDS:
bio-based adhesive, citric acid, engineered properties, structural wood product

The utilization of bonding systems based on natural and renewable resources is a subjected that has been extensively studied. It has been demonstrated the feasibility of using citric acid for bonding wood and since there several authors have shown the potential of this natural product to manufacture particleboards from several types of biomasses. All these research papers described the potential for bonding wood fiber/particle composites. The first paper published about using only citric acid for bonding wood veneer showed very encouraging results. In this context, the present paper aims to present the production and properties of laminated veneer lumber (LVL), a kind of veneer-based wood composite, bonded with citric acid and melamine-urea-formaldehyde (MUF). LVL composite boards were manufactured following three treatments: T1, 10% citric acid bonded LVL; T2, citric acid-MUF bonded LVL and MUF bonded LVL. Ten-layer LVL billet (400 mm x 400 mm x 22 mm) was hot-pressed using a 4-step pressing schedule: 180ºC, 1.0 MPa for 5 minutes; 2.5 MPa for 10 minutes; 1.0 MPa for 2:30 minutes and 0.5 MPa for 2:30 minutes. The choosing of these pressing parameters was based on screening research previously developed. This schedule was applied aiming at the consolidation and densification of the board at same operation and it was performed using Joos Lap 150 (Pfalzgrafenweiler, Germany) laboratorypress. An INSTRON 4467 universal testing machine was used to assess bending properties (modulus of rupture, fm and modulus of elasticity, EM) and compression parallel to the grain strength (fc,0). The bonding quality was evaluated by assessing the glue-line shear strength (fgv,0) at dry conditions. Thickness swelling and water absorption (TS/WA) tests were also performed. Profile x-ray densitometry was performed using Fagus-GreCon DAX-5000 (Germany) densitometer. Analysis of variance followed by mean test was run to identify the difference between treatment Mechanical properties of the LVL composites are showed in Table 2. The fgv,0 for all three treatments exceeded the minimum requirement (1 N/mm2). Additionally, bending strength and stiffness, and parallel compression strength were similar or higher than those found in the literature for LVL bonded with synthetic resins. All the bending samples failed by tension on the outer bottom side veneer. It can be concluded that citric acid has great potential to be used for manufacturing LVL composite board and boards bonded with MUF presented better properties.

FUEL PROPERITES OF PAULOWNIA RBTC15 CLONE

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KEYWORDS:
Paulownia RBTC15, short rotation coppice, fuelwood properties

Paulownia is a fast-growing species widely used in China. It is expected that it won't be possible to satisfy growing needs for energy wood from natural forests alone. One of the solutions to bridge the gap is the cultivation of fast-growing species. This research dealt with the possibilities of Paulownia's usage as a solid biofuel and its properties. The research was conducted in Požeško-slavonska county (45°21'20.4"N 17°38'33.0"E) on seven agricultural fields that are planted with Paulownia RBTC15 clone. The above-ground part of the sampled trees was one to four years old. The samples for laboratory analyses were taken from the root (from three dominate root branches), trunk (one at each meter of length), crown (from three dominate crown branches), and leaves. The moisture, ash, carbon, nitrogen, hydrogen, and sulphur content were determined as well as net calorific value according to the HRN EN ISO standards. The results of the physical and chemical properties of Paulownia wood were compared with the properties of the usually used raw material for energy production in Croatia. The highest moisture content was found in the root (81.15±2.7%), followed by the leaves (72.94±0.69%), trunk (61.52±3.2%), and crown (57.51±4.4%). The leaves had the highest average ash content 7.4% (6.0-9.7%) followed by the root 4.2% (2.6-5.9%), tree crown 1.6% (1.2-2.2%), and trunk 1.3% (1.0-1.6%). The net calorific value ranged from 18.27 MJ/kg (for the tree trunk) to 17.20 MJ/kg (for the root). Compared to the other species that are commonly used for short rotation coppice (willow and poplar), Paulownia wood has similar fuel properties. In terms of important and comparable fuel properties, Paulownia wood (trunk and crown) has 27.5% lower ash content, and slightly lower (0.71%) net calorific value than typical values of poplar and willow. Compared to the typical values of broad-leaf logging residues commonly used for energy production in Croatia, Paulownia wood shows significantly lower ash content (by 71%), but also lower net calorific value (by 2.30%). Regarding the researched fuel properties, Paulownia wood can be used for energy production similarly to the commonly used logging residues, but with the special emphasis on wood density, which is in the case of Paulownia wood, on average, three times lower, and could pose additional challenges in the wood supply chain.

EVALUATING THE POTENTIAL FOR EXTERIOR USE OF PLYWOOD PANELS COMPOSED OF THERMALLY MODIFIED POPLAR VENEERS

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KEYWORDS:
Basidiomycete fungi, Exterior, Thermal modification, Plywood durability

This research examines the influence of brown rot fungus *Serpula lacrymans* and white rot fungus Trametes versicolor on durability of plywood panels composed of thermally modified poplar veneers. Five types of five-layer plywood panels have been tested, the control panel made of unmodified poplar veneers and four plywood panels composed of thermally modified veneers at temperatures of 190, 200, 210 and 215° C. The results showed that the impact of thermal modification was positive, and that this environmentally acceptable process increases the durability of the treated material against wood destroying basidiomycetes fungi.

RAMAN MICROSPECTROSCOPY OF "TENSILE FLEXURE WOOD" IN *POPULUS X EURAMERICANA*

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KEYWORDS:
cell wall, gelatinous fibers, Populus x euramericana cl. NS 11-8, tensile flexure wood

Woody plants in response to gravitropic or phototropic environmental stimuli develop a reaction wood to overcome stem lean. Reaction wood in Angiosperms is called tension wood (TW). TW contains more cellulose and less lignin. TW fibers, gelatinous fibers (G-fibers), differ anatomically from normal wood (NW) fibers formed in the absence of stimuli. Typical G-fibers are characterized by an inner gelatinous (G) cell wall (CW) layer. On the other hand, in response to mechanical stress, such as strong wind or artificial bending treatments, woody plants develop "flexure wood". "Flexure wood" formed under tension in Angiosperms is termed "tensile flexure wood" (TFW). In comparison with TW, TFW fibers are characterized by a thinner G-layer but also a thinner S-layer. TFW, similarly to TW, represents an increased source of non-recalcitrant cellulose for biofuel production. The efficiency of bioethanol production depends on lignocellulose composition. It increases with higher cellulose content, lower cellulose crystallinity (hemicellulose/cellulose ratio), lower lignin content, higher coniferaldehyde content, higher syringyl (S) to guaiacyl (G) ratio, and lower ash content. We performed histochemical, SEM, and Raman microspectroscopic analysis of NW and TFW on the cross sections of juvenile Populus x euramericana trees formed as a response to severe long-term static bending. Histochemical analysis shows the difference in lignin distribution in different CW layers of NW and TFW fibers and the presence of phenolic or lignin-like substances in the G-layer. SEM micrographs present the differences in CW shape, thickness, and ultrastructure between NW and TFW fibers. Raman microspectroscopy provides a spatial distribution of CW components in NW and TFW fibers. The difference in the structure of cellulose, hemicellulose and pectin, but also lignin, is suggested in CWs of TFW compared to NW, based on the shifts of the bands at 1100 cm-1, 835 and 655 cm-1 characteristic for cellulose, hemicellulose and pectin, the band at 1587 cm-1 assigned to lignin, and the band at 1687 cm-1 assigned to coniferyl alcohol and coniferaldehyde. In addition, the higher S/G ratio in TFW compared to NW is suggested. Presented preliminary data encourage further work on *P. euramericana* TFW examination for biofuel production. Planting *P. euramericana* windbreak forests could provide TFW as an increased source of non-recalcitrant cellulose for biofuel production.

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Session F:

SILVICULTURE AND ECOSYSTEM MANAGEMENT

HOW DYNAMIC ARE STRUCTURAL AND COMPOSITIONAL CHANGES AT A FINE-SCALE LEVEL? AN EXAMPLE FROM THE STRICTLY PROTECTED FORESTS OF ROZTOCZE NATIONAL PARK IN POLAND

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KEYWORDS:
basal area trajectories, fine-scale patches, forest dynamics, primary forests

Forest managers are expected to emulate the structural patterns and disturbance regimes of reference primary forests to the greatest extent possible. In this context, the forest cycle theory, established during the 20th century and widely adopted by many forest researchers and practitioners with little or no critique, suggests that particular patches (groups of trees) within an old-growth stand develop linearly, progressing through stages from regeneration and initial growth to optimal and, finally, breakdown stages. However, due to the lack of long-term observations with detailed tree position data, little research has been conducted on this subject. Our study focused on proxy small-scale spatial dynamics based on patches of living trees for which exact positions and diameters were recorded from 1993 to 2023. First, we analyzed changes at the stand level in terms of diameter distributions and tree species composition over three decades. The distributions of European beech and silver fir remained relatively stable, while the cumulative distribution changed significantly due to a noticeable decrease in young trees of minor species. Secondly, we investigated the dynamics of basal area (BA) changes at the sub-stand level on small patches ranging from 0.01 ha to 0.0625 ha for each decade and over the entire observation period. At the decadal level, spatially random single-tree mortality was the predominant disturbance pattern. However, over a longer period, some of these small disturbances repeatedly occurred and concentrated at the same microlocations within the forest, which eventually resulted in spatially aggregated losses of BA by the end of the observation period. Another important finding from this study was that patches with non-directional BA dynamics were more common than those with continual positive BA accretion and/or continual negative BA trajectories. This finding significantly challenges the premises of linear patch development.

DAMAGE TO NARROW-LEAVED ASH (*FRAXINUS ANGUSTIFOLIA* VAHL) AND GREEN ASH (*FRAXINUS PENNSYLVANICA* MARSHALL) IN RELATION TO TREE ATTRIBUTES AND STAND STRUCTURE IN CROATIAN LOWLAND FORESTS

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KEYWORDS:
ash dieback, invasive species, stand structure, tree crown damage, tree slenderness coefficient

Narrow-leaved ash (*Fraxinus angustifolia* Vahl) makes up 3,19% of forest growing stock in Croatia, being of more bio-ecological than economic value. It is eurivalent species that grows from the marsh border of forest to the mixed floodplain forests in which it has a significant role. Sporadically, within native ash forests there thrives green ash (*Fraxinus pennsylvanica* Marshall) that was planted or spread from nurseries. Both species are endangered due to novel disease caused by *Hymenoscyphus fraxineus* Baral. The assumption is that the morphological characteristics of trees (e.g., larger crown volume and less slenderness) and stand structure (smaller stocking, density and growing stock), as well as the tree species, can have a positive effect on resistance to that disease. The aim of research was to investigate differences in tree crown damage and growth characteristics of the two ash species, regarding to tree and stand attributes. The research was carried out in 10 narrow-leaved ash forest stands in the region of Central Posavina (Croatia). Systematic sample of 43 circular plots was used to measure tree attributes (height, diameter at breast height (dbh), tree crown volume, intensity of crown damage) and elements of stand structure (density, basal area (BA), stocking, growing stock). In total, 1100 trees were measured on the 1,56 ha with an average basal area 25,3 m²/ha (ranging from 10,4 to 55,4). Increment cores to the pith were taken from the 40 green ash and 114 narrow-leaved ash trees. Average tree age is 43,4 years (range: 9 – 103), slenderness coefficient (SC) is 83,9 (range: 42,7 – 143,6) and crown volume 207,2 m³ (range: 1,1 – 1625,7). Tree cores enabled estimating the dynamics of radial growth and computing the index of increment change (RGI) since the appearance of the novel disease. T-test and factorial ANOVA were used with 5% significance level. Tree crown damage and RGI were compared between the categories of tree slenderness, crown volume and stand BA for the two species. Species differ in tree and stand characteristics – green ash has a greater average dbh, age and crown volume, while less SC, crown damage and lower BA (effect of thinning or planting). Although according to the previous research, the radial growth of green ash stagnates from a young age, the difference in RGI between the species has not been proven (p=0,839). The ANOVA proved that less damaged crown have trees with a larger crown (F(3, 146)=4,09, p=0,008) and smaller stand BA (F(3, 150)=3,03, p=0,031). RGI was higher for slender trees (F(2, 151)=2,18, p=,116) and lower for greater stand BA (F(3, 150)=2,55, p=,058). The tree species was not statistically significant factor in any case for both variables. Trees with a smaller crown in overstocked stands are more susceptible to crown damage. Observed differences between the species can be attributed to different stand structure and stand establishment. The resistance of trees can be improved by adaptive management that supports uneven-aged and uneven-sized stand structures with timely silvicultural treatments. Due to healthier crown with more frequent and abundant seed yield, further expansion of green ash can be expected.

FUNGI ASSOCIATED WITH CROWN DIEBACK OF *Quercus robur* L. IN EASTERN CROATIA

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KEYWORDS:
bark necrosis, Diaporthe eres, pathogenicity, pedunculate oak, wood necrosis

In June 2020, stem and branch cankers were observed on young *Q. robur* trees growing in the natural six-year-old floodplain forest stand in the Sava River basin in the eastern part of Croatia. It was hypothesized that fungal pathogens might have caused these symptoms, and the following aims were set in this research: (1) to isolate and identify fungi present in the necrotic tissue; and (2) to test the pathogenicity of the most frequently isolated fungal species on *Q. robur* saplings. Samples of affected stems and branches were randomly collected from 13 trees, and fungi present in the symptomatic tissue isolated on agar media. The molecular and morphological identification of obtained mycelia revealed 27 fungal isolates belonging to 12 different taxa. The most frequently isolated species was D. eres. Other fungi (*Neocucurbitaria sp., Dendrostoma leiphaemia, Monochaetia sp., Alternaria sp.1, Alternaria sp.2, Cladosporium cladosporioides, Didymellaceae sp., Paraconiothyrium brasiliense, Paraphaeosphaeria sp., Sordaria fimicola, Valsa ceratophora*) were represented with only 1-3 isolates and mostly present on only one tree. The ability of D. eres to cause cankers was tested in a pathogenicity trial on 3-year-old *Q. robur* saplings. Bark and wood necroses developed on all infected saplings, and *D. eres* was successfully re-isolated and identified using molecular tools. None of the control saplings revealed any symptoms during the trial. Therefore, Koch's postulates were fulfilled, and *D. eres* was verified as a causative agent of cankers on *Q. robur*. However, since the fungus wasn't confirmed on all naturally affected trees, and it caused relatively mild symptoms in a six-week pathogenicity trial, it should be considered as a minor pathogen of *Q. robur*. There is a possibility that the fungus was already present in the healthy wood or bark of *Q. robur* in the studied floodplain forest as an endophyte, and that it shifted to a pathogenic lifestyle and caused cankers on those plants which experienced a loss of vitality due to other factors. *Q. robur* in eastern Croatia has shown to be highly susceptible to climate change and availability of water, and it is often exposed to severe attacks by an invasive pest, *Corythuca arcuata*. It is possible that the young oak trees in this study underwent the loss of vitality caused by some of these factors, and that the other isolated fungi along with *D. eres*, shifted from endophytic to parasitic lifestyle and contributed to the development of cankers.

DEVELOPING PREDICTION MODEL FOR BROWN BEAR TIMBER DAMAGES: A CASE OF UNPREDICTABILITY

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KEYWORDS:
Abies alba,
AIC,
CIC points,
Ursus arctos

According to scientific reports, brown bear timber damages in Europe appeared at the end of 70s in the 20th century. They are expressed as bark stripping and usually are connected with higher bear population density although the real reasons are still not enough clear. According to research of the problem during five years (2009-2013) in selective silver fir stands bears choose thicker trees (*t*=-3,857; *p*<0,001) then average stand diameter in clustered pattern (*NNR*=0,287; *z-score*=-19,383; p<0,000001). The prediction model was developed using trophy values (pelt dimension), distribution of feeding (lure) places and forest inventory data, but the model shows low accuracy (*Nagelkerke* R^2=0,184).

UNVEILING THE CONNECTION: LANDSCAPE CHARACTERISATION, FOREST HEALTH AND LEOPARD POPULATION IN NORTHERN ARAVALLI LANDSCAPE, INDIA

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KEYWORDS:
Forest fragmentation, Forest health, Landscape characterisation, Leopard, LULC

Healthy population of large carnivore is often associated with the healthy forest ecosystem. Many studies in recent past have revealed that obligate carnivores are increasingly forced to move out of the forest areas, adapting to human dominated landscapes. This dispersion is owing to various factors like forest degradation, fragmentation, diversion of forest land to agriculture & settlements as well as Inter & Intra specific competitions. The dispersing carnivores often seek refuge in the adjacent forest and other suitable habitat patches. Leopards (*Panthera pardus*), amongst other large carnivores are highly adaptable and can survive in a range of environments. A notable presence and subsequent breeding of leopards has been observed in Northern Aravalli Landscape in spite of comprising three major metropolitan cities of the country. To elucidate the underlying mechanisms driving this phenomenon, we employed a comprehensive multidisciplinary approach: integrating forest inventory, habitat fragmentation analysis, forest health parameters (FHPs), camera trap based faunal inventory, landscape characterization and land use land cover (LULC) change detection (2003-2023) which revealed significant alterations in forest cover and habitat composition in the study area. Leopard population estimation was also carried out based on spatial capture-recapture framework. During 588 camera trap nights, eight individual leopards were detected with density of 4.5 $\pm$ 0.019 leopards/100km^2 despite very high anthropogenic pressure. Our results indicate a significant positive correlation between FHPs (canopy cover, basal area, and tree species diversity) and leopard population density. Preliminary analysis suggests that the augmentation of forest cover within the protected area, facilitated by targeted conservation efforts by the forest department, may be a primary driver of the forest health. Furthermore, habitat degradation in adjacent areas could be triggering a meta-population shift, leading to an influx of leopards into the landscape. It is suggested that maintaining optimal FHPs is crucial for supporting healthy leopard populations. The findings have implications for sustainable forest management and wildlife conservation in human-dominated landscapes. Our research will contribute significantly to a nuanced understanding of the complex interplay between habitat quality, wildlife migration patterns, and population dynamics, informing evidence-based conservation strategies for this apex predator.

ANALYSIS OF LAND USE AND LAND COVER DYNAMICS IN DAMDAMA WETLAND, GURUGRAM, INDIA USING MULTIPLE CHANGE DETECTION METHODS

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KEYWORDS:
Geographic Information System, remote sensing, wetland, Pre-monsoon, Post-monsoon

The degradation of water quality, loss of habitat, and the destruction of both terrestrial and aquatic ecosystems are significant global environmental concerns. Wetland ecosystems, in particular, have experienced substantial transformations due to human activities like urbanization, agriculture, and industrial expansion. This study aimed to monitor the changes in and around the Damdama wetland using remote sensing and geographic information systems (GIS). Land use and land cover (LULC) changes were analyzed for the period from 2010 to 2020, focusing on two seasons: pre-monsoon and post-monsoon, using ERDAS Imagine 2014 software. The LULC classification was carried out based on six categories: agriculture, barren land, built-up areas, fallow land, vegetation, and waterbodies, using a maximum-likelihood supervised classification approach. The results revealed an increase in agriculture, barren land, built-up areas, and waterbodies by 9.41%, 14.83%, 3.95%, and 0.15% during the pre-monsoon season between 2010 and 2020. However, fallow land and vegetation decreased by 15.15% and 13.20%, respectively. During the post-monsoon season, barren land, built-up areas, and fallow land grew by 9.6%, 4.13%, and 1.38%, respectively, while agriculture, vegetation, and waterbodies declined by 6.5%, 8.42%, and 0.19%. The study achieved overall accuracy rates of 90% and 92% for the pre-monsoon and post-monsoon seasons, respectively, in 2010, and 94% for both seasons in 2020. These findings indicated that the three different analytical techniques used to assess the changes showed consistent trends. Overall, such land use transformations pose a potential threat to the future sustainability of wetland ecosystems.

ROLE OF LIVING LABS IN INTEGRATING SOCIETAL DEMANDS WITH BIODIVERSITY CONSERVATION

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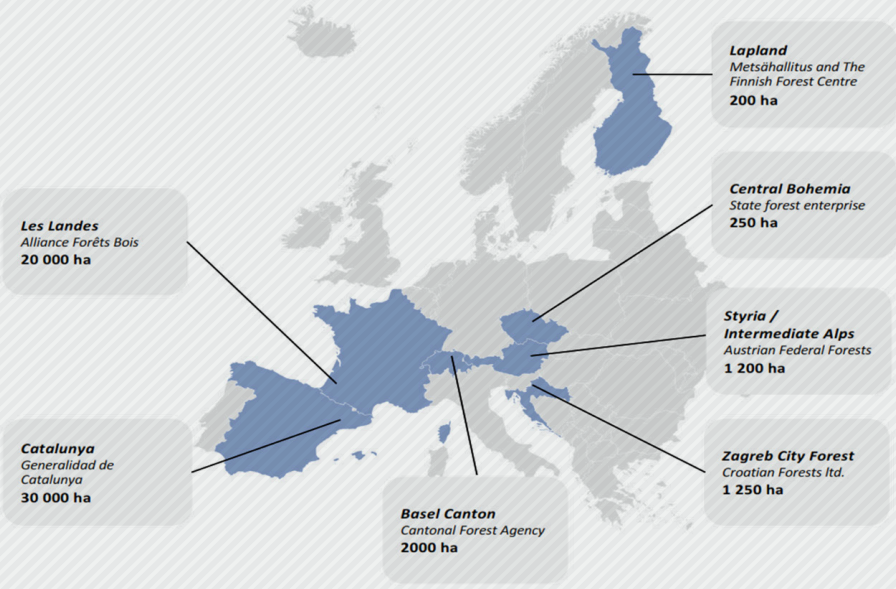
KEYWORDS:
Living Lab, integrative forest management, biodiversity conservation

Project TRANSFORMIT (Transforming forest management for multiple ecosystem services and nature conservation via the integrative approach) aims to demonstrate and improve the effectiveness of different integrative forest management (IFM) approaches, which are in use in several countries. Through a combination of productive forestry and biodiversity conservation integrated into existing practices, and scientific knowledge, the project will foster collaboration and mutual learning amongst science, policy, and practice in Europe and internationally.

The newly established network of seven Living Labs - LLs (Map) will provide in-depth insights into different IFM approaches, and their common and specific challenges. Project vise, the role of LLs is crucial and will be manifold. Ranging from a description of the LL area and present IFM approach to participating in the selection of indicators of IFM, and decision support tools to be improved and tested to contribute to the knowledge hub through collaborative and co-creative processes engaging main stakeholders working together on providing solutions to present and future challenges.



Map of LLs
Those seven Living Labs will serve as role models to spread IFM across European regions.

THE ROLE OF RUBBER PLANTATIONS IN ECOSYSTEM MANAGEMENT: INSIGHTS FROM CO_2 SEQUESTRATION IN TRIPURA

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KEYWORDS:
CO_2 sequestration, Ecosystem Management, Rubber plantations, Tripura.

Rubber plantation is a potential solution for carbon sequestration and can be used in ecosystem management, climate change adaptation, and mitigation. This study examines the CO2 sequestration potential of different age compartments of rubber plantations located in different regions of Tripura such as Kalshimukh, Laxmipati, Pathalia, Kalamchoura, and Killa. The total biomass values for these plantations vary, i.e. 1.87 tonnes per ha. in younger plantations (8 years) to 4.12 tonnes per ha. (32 years) old plantation. Our results reveal that the accumulation of biomass and carbon stock is positively correlated with plantation age, highlighting the more effective carbon-sinking capacity of older rubber plantations.

These findings demonstrate the significance of rubber plantations in carbon capture, particularly when managed for long-term sustainability. Such plantations can be integral components of ecosystem management strategies, not only for their economic value in rubber production but also for their ecological services, including carbon sequestration and biodiversity support. By optimizing rubber tree cultivation, particularly through extending plantation age and improving management practices, these ecosystems can enhance their contribution to mitigating climate change while providing long-term environmental benefits.

NEEM TREE IMPROVEMENT FOR THE DEVELOPMENT OF SUSTAINABLE BIOECONOMY AND LIVELIHOOD OF FARMERS

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KEYWORDS:
Bioeconomy, Productivity, Climate change, Commercial cultivation, Superior Progenies

Neem tree improvement has strategically become a crucial proponent in the development of bioeconomy and climate change mitigation. The most prominent biochemical component of neem oil is azadirachtin, responsible for antibacterial, antifungal, insecticidal, pesticidal and antioxidant properties. Introduction and utilization of 100% neem coated urea as per directions of the Government of India, has led to a substantial increase in demand for neem oil to bridge the increased gap, neem oil adoption of superior progenies that produce high quantities of neem seeds with elevated levels of azadirachtin content is inevitable. The present study was therefore directed towards screening and evaluation of superior progenies for various growth parameters that ultimately influence productivity so that different growers including farmers and oil-based industries could deploy these genetically superior genotypes on a commercial scale to ultimately improve farmer's income. During present investigations, twenty-four progenies of Azadirachta indica were evaluated for six years over different geographical locations. The analysis depicted significant variation in traits investigated viz. tree height, collar diameter, diameter at breast height, clear bole height, crown height, crown width, and crown shape. The results indicate the existence of wide variability for future genetic improvement as well as the scope of adoption of improved genotypes by farmers for commercial deployment. The identified genotypes can easily be considered for meeting the necessary germplasm requirement of breeding strategies for genetic improvement, development of bioeconomy, and combating climate change.

WHAT IS FRUITDIV IN EUROPEAN INITIATIVE ABOUT FORESTS FRUIT

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Crop wild relatives (CWR) are wild plant taxa closely related to a crop. They represent an important source of genetic diversity for the improvement of agronomic traits and they are still available as tree species within the European forests. In the context of the One Health Initiative, temperate fruit trees are essential for human nutrition and health, yet CWR resources have hitherto been underused. Moreover, fruit tree long lifespan and a current production dominated by a few cultivars make them particularly vulnerable to the effects of global changes. To address this challenge, the FRUITDIV project will monitor, characterize, use, and conserve the diversity of emblematic fruit tree CWR, with a particular emphasis on Malus, Pyrus and Prunus, by linking horticulturists, forestry officers and citizens.

To better characterize the genetic and phenotypic diversity of CWR fruit trees and identify favourable traits for future introgression into cultivars, FRUITDIV will use a combination of floristic, ethnogeography and population genomics on genebanks and historical European hotspots of diversity. We will then develop new multiomics-based breeding strategies that combine marker assisted introgression for traits of interest (e.g. resilience, resistance to pests and diseases, fruit quality) with pangenomic prediction and a reduction of CWR associated genetic load.

In addition to breeding programs, FRUITDIV will also work with networks of farmers and associations to help characterize CWR progeny in various pedo-climatic conditions in Europe. An European-wide online platform that provides genotyping and phenotyping data for free will be implemented to promote the use of CWR genitors by breeders and farmers and help disseminate plant material of interest for various usages and cultivation systems.

Overall, the FRUITDIV multi-actor approach involving geneticists, forestry officers, germplasm curators, farmers and citizens, will foster the in- and ex-situ conservation of Fruit tree CWR and promote sustainable agricultural and forestry practices across Europe.

FRUITDIV is by essence inter-disciplinary, gathering experts in horticulture, forestry, ecology, genetics and population genetics, genomics, bioinformatics, mathematics and social sciences. It is made of 27 partners from 10 EU countries and 4 non-EU countries. The above 5 authors will represent the consortium at the IUFRO conference.

IN VITRO CONSERVATION OF NARROW-LEAVED ASH IN CROATIA - ADVANTAGES AND RISKS

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KEYWORDS:
ash dieback,
Fraxinus angustifolia,
gene bank,
tissue culture

Narrow-leaved ash (*Fraxinus angustifolia* Vahl.) is economically and ecologically significant tree species in the lowland floodplain forests of the Republic of Croatia. However, this species faces numerous threats, including habitat loss, climate change, and diseases such as ash dieback caused by the invasive fungus *Hymenoscyphus fraxineus*. In response to these challenges, *in vitro* conservation techniques have emerged as a critical strategy for preserving narrow-leaved ash populations in Croatia. This study investigates the use of in vitro conservation techniques for preserving the threatened narrow-leaved ash in Croatia. *In vitro* gene banks, which involve the cultivation of plant tissue in sterile nutrient media under controlled environmental conditions, are playing an increasingly important role in the conservation of vegetatively propagated and endangered plant species. This method not only helps protect genotypes threatened by habitat loss and climate change but also provides opportunities for restoring populations in their natural habitats. For the past four years, we have focused on identifying potentially resistant individuals of the narrow-leaved ash in endangered forest stands. Following that, we have been working on establishing protocols for micropropagation and preservation of the narrow-leaved ash in vitro. Several protocols were tested in the laboratory, and the most optimal one was selected for future research. A difference in the success of micropropagation was observed depending on the origin of the plant material, as well as depending on different procedures with the plant material before and during micropropagation in the laboratory. The developed technology, along with resistance testing of selected individuals, could greatly contribute to the conservation of the narrow-leaved ash in the future.

CHARACTERISTICS OF SEEDS AND SEEDLINGS FROM THE MARGINAL POPULATION OF PEDUNCULATE OAK (*Quercus robur* L.) FROM LIVANJSKO POLJE

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KEYWORDS:
penduculate oak,
variability,
seed and seedlings

The pedunculate oak (*Quercus robur*) is significant economic species in Bosnia and Herzegovina. It is spread across numerous locations, many of which are characterized as marginal or peripheral. Livanjsko polje represents one of these locations where the pedunculate oak finds its habitat. Due to anthropogenic factors such as the use of wood for wood fuel, clearing areas for livestock grazing, and fires, the pedunculate oak often appears in the form of individual, damaged trees or small forest areas, primarily in coppice form. Natural regeneration is almost non-existent

In 2023, a good seed yield of the pedunculate oak was observed. Sixty-two trees from three locations in the Livanjsko Polje were selected, and seeds were collected. The seeds were processed and measured, including: acorn length, diameter at the widest part, diameter at the base, length up to the widest part, and acorn mass. In December 2023, seeds were sown in BCC containers HIKO 250. The seedlings were measured in June 2024, recording seedling height, root collar diameter, and the number of leaves. Statistical analysis of the data revealed variability at the level of half-sibling lines for seed and seedling dimensions and correlations among the observed parameters

The results indicate a high level of variability at the half-sibling line level for the observed acorn dimension characteristics. A significant correlation was found between acorn width and seed mass, while other characteristics did not show statistically significant correlations. A significant level of variability was determined for seedling dimensions. The most variable trait was seedling height, while the least variability was found for root collar diameter. No correlation was found between the morphometric parameters of seeds and seedlings.

The variability of pedunculate oak in marginal and peripheral populations should be preserved through reintroduction processes. Analysis of the variability of forest reproductive material, seeds, and seedlings is one of the first steps in defining the state of variability and need for the successful restoration of the species in its existing habitats

SUPERVISION OF SPRUCE BARK BEETLE ATTACKS SUPPORTED WITH REMOTE SENSING IN THE NORTH-EAST BOSNIA

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KEYWORDS:
Ips typographus, insect traps locations, intra-seasonal variation, NDRS index, Sentinel S2 imagery

Traditional forest management, relied on terrestrial observations only, leads to some doubts about causes of insect attacks, particularly in mixed stands with spruce and artificial spruce stands. Available satellite data and proposed spectral indices enable insight in interactions between spectral responses and forest site characteristics during the vegetation season covering changes influential for forest stability. The aim of this study was to clarify effects of site types where traps were distributed (logging unit, smaller wood depot and stand with low forest order) on total number of trapped bark beetles in spruce dominated stands using integrative terrestrial and remote sensing approach in the north-east Bosnia and Herzegovina. In addition, we examined changes of spectral Normalized Distance Red & SWIR index (NDRS), as forest vitality indicator, determined monthly, to clarify intra-seasonal differences between site types. Terrestrial data contained counts of trapped bark beetles at the end of vegetation season from 53 traps distributed on forested area in Tuzla canton. Spectral indices were derived using Sentinel image monthly time-series from the same vegetation season. Differences between counts of trapped bark beetles were examined using non-parametrical one-way analysis of variance (ANOVA). Differences of spectral indices between site types in vegetation season were analysed using repeated measures ANOVA (RM-ANOVA). Total number of captured beetles at the end of vegetation season was ranged from 0 to 11130 on all site types with median value of 280. There was no significant difference in total number of captured beetles between investigated site types ($p=.75$). Related to spectral indices, the RM-ANOVA resulted in significant differences between NDRS values in interaction site type x month ($p<0.01$) differentiating lower wood depots with averagely higher NDRS pixel values compared to logging units and stands with low forest order during the whole vegetation season. Obtained results indicated lower vitality of stands near smaller wood depots then on stands near logging units and with low forest order. So, higher attention should be paid on smaller wood depot locations to avoid insect's attraction. As important fact we candidate notifications of appearance of one extreme bark beetles attack at each site type, what emphasises a need for more efficient control. We found out that integrative remote sensing and traditional terrestrial control approach gives better insight in spatial-temporal effects of bark beetle attacks and strengths supervision of bark beetle density on larger forested area.

FOREST PESTS IN AFTERMATH OF BARK BEETLE OUTBREAKS IN UNE-VEN-AGED FIR STANDS

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KEYWORDS:
natural forest regeneration, unevenaged management, curculionidae, climate change

Climatic changes in the last 40 years caused an average rate of increase in temperature per decade more than twice as fast and are followed by an increase in extreme precipitation. This leads to increased pressure on forests in the form of low resistance of trees to harmful events of biotic and abiotic nature. In the Republic of Croatia, in Gorski Kotar County, research was conducted on areas after performed clear-cuts due to a bark beetle outbreak in 2017. In total seven areas of 58.13 ha were measured: 1) Gornja Dobra (Management Unit – MU Goranska Dobra) 5.24 ha, 2) Carevići 1 (MU Miletka) 16.52 ha, 3) Carevići 2 (MU Miletka), 3.32 ha, 4) Radoševići (MU Miletka) 6.14 ha, 5) Lučice (MU Delnice) 15.89 ha, 6) Sunger 1 (MU Sunger) 8.44 ha and 7) Sunger 2 (MU Sunger) 3.59 ha. The stands are characterised as an uneven-managed (selective) forest of spruce (Picea abies (L.) Karsten) and fir (Abies alba L.). Transects were made in each of the seven areas, and the health condition of all tree species was examined. It was found that several species were predominant. Most pests recorded were determined on the leaves of deciduous species, especially on beech, such as leaf miners, gall midges and weevils.

ANALYZING LAND USE LAND COVER (LULC) AND NDVI TRENDS IN LOKTAK LAKE: INSIGHTS FOR ECOSYSTEM MANAGEMENT AND UNESCO GLOBAL GEOPARK DESIGNATION

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KEYWORDS:
Land Use Land Cover (LULC) dynamics, Loktak Lake, Normalized Difference Vegetation Index (NDVI), UNESCO Global Geopark

Loktak Lake, the largest freshwater lake in northeastern India, is a unique wetland ecosystem characterized by its floating phumdis (vegetation mats) and rich biodiversity catering the livelihood needs for thousands of people. The lake has a surface area of 287 square kilometers, a maximum length of around 32 kilometers, and a width of 13 kilometers. This study aims to examine the Land Use Land Cover (LULC) dynamics and Normalized Difference Vegetation Index (NDVI) of Loktak Lake over five key years: 1978, 1989, 2000, 2011, and 2022. Utilizing remote sensing and GIS technologies, the study analyzes the impact of anthropogenic activities and management interventions on the lake's ecological health. The findings reveal significant changes in LULC, with a notable increase in agricultural land as well as fish farms and a decrease in open water and phumdi areas, particularly due to urbanization and unsustainable fishing practices. The NDVI analysis indicates fluctuations in vegetation health, reflecting the lake's ecological stress and the effects of conservation efforts in the 44 year timeline. Furthermore, this study discusses the potential of Loktak Lake to be designated as a UNESCO Global Geopark, highlighting its geological significance, biodiversity, and cultural heritage. The Integrated Management Plan (IMP) for Loktak Lake, a collaborative effort between Wetlands International South Asia (WISA) and the Indian Institute of Technology (IIT), Roorkee, approved in the year 2024, aims to enhance ecosystem management, ensuring sustainable use of resources while preserving the unique landscape. However, the management challenges, including pollution due to fertilizers and pesticides from the surrounding agricultural land and solid waste material from the rivers flowing into the lake, encroachment, and unsustainable fishing practices, need to be addressed to meet the criteria for a UNESCO Global Geopark. This study underscores the importance of strategic conservation efforts and community involvement in maintaining Loktak Lake's ecological integrity, positioning it as a vital candidate for global recognition.

BACTERIAL TREATMENT PROMOTES THE GROWTH OF TWO-YEAR-OLD SESSILE OAK (*Q. PETRAEA* (MATT.) LIEBL) SEEDLINGS PRODUCED FROM DAMAGED ACORNS

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Bacillus,
Pseudomonas,
seedlings,
sessile oak,
growth promotion

Plant growth-promoting bacteria (PGPB) are a diverse group of microorganisms that support plant growth and development by hormone production, nutrient sequestration, and biocontrol activity. Nowadays they are used as an ecologically acceptable alternative to chemical fertilizers and pesticides, and their significance is especially emphasized during seed germination and plant survival in unfavorable environmental conditions. Oak acorns are seeds that are very rich with nutrients and are food for many animals, whereby their germination is endangered, and the growth of such seedlings stagnates. In this study, two-year-old sessile oak seedlings produced from acorns damaged with drillings from pest attack were treated with bacteria for which it was demonstrated in vitro plant growth-promoting potential, with the aim to investigate their effect on the quality of the seedlings that originate from damaged acorns. For treatment preparation, two bacteria were used, from Bacillus and Pseudomonas genera. At the end of the growing season, seedling height and root collar diameter were measured by a ruler and vernier caliper, and based on the obtained data seedling growth and root collar diameter increment were calculated. For data statistical analysis in SPSS 27 software package ANOVA or GLM were used, depending on the fulfillment of the conditions for their application. Results indicate a statistically significant difference between bacterial treatments and the control group for seedling height and root collar diameter values, where seedlings treated with bacterial inoculum were more successful. The mean values of seedling height increment were higher for both bacterial treatments compared to the control group, although differences were not statistically significant. Differences in seedling root collar diameter increment between bacterial treatments and control group were not statistically significant as well, although Bacillus treatment group had higher mean values in comparison to the control group. The obtained results confirm beneficial effect of Bacillus and Pseudomonas bacterial genera on seedling growth and development, which can be used as an auxiliary measure in seedling production from damaged acorns.

CROATIAN KNOW-HOW – ADVANCING BIODIVERSITY, ECOSYSTEM CONDITION AND SERVICES IN VARIOUS SPATIAL CONTEXTS

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KEYWORDS:
biodiversity, decision-making, ecosystems, environment, implementation

The concepts of biodiversity, ecosystem condition and ecosystem services are in the focus of today's environmental decision-making, especially in Europe. Both the public and private sectors utilise these concepts to provide effective and integrated solutions to numerous challenges society is facing today. Like the rest of Europe, Croatia is implementing biodiversity, ecosystem condition and ecosystem services concepts in different spatial settings and decision-making processes. To understand how these concepts are applied and consequently advanced on a national level we have gathered a multidisciplinary team of experts from the public and private sectors who have significant experience in practical implementation of mentioned concepts. Multidisciplinary team organised in the Community of Practice Croatia, as part of the SELINA EU Horizon project, discussed and summarised approaches currently applied in Croatia for looking at biodiversity, ecosystem condition and ecosystem services in different spatial and managerial contexts. The Community of Practice analysed studies in Croatia regarding ecosystem assessments. They examined the structure and number of studies related to ecosystem condition and ecosystem services assessment and evaluated whether they are equally distributed across different ecosystem types. Results show that the concepts are applied to different types of natural and urban ecosystems, aiming to assess the current condition, possible effects development can have on them and proposing sustainable solutions, often in lieu of nature-based solutions, to improve the ecosystem condition for biodiversity and human communities and enhance the provision of ecosystem services. Analysed examples range from highly anthropogenic ecosystems (e.g., urban green spaces or regulated watercourses) to protected natural areas. Assessment results and proposed solutions can then be incorporated into various strategic and management plans, project proposals or be used to amend/improve the proposed development projects. There is still room for improvement in implementing the concepts of biodiversity, ecosystem condition and ecosystem services in Croatia, but there is an agreement that concepts offer great opportunities for comprehensive assessment of ecosystems. Regardless of the spatial context, the goal is to have healthy, stable, and biodiversity-rich ecosystems that provide different services to people today and in the future. Experts gathered around the Community of Practice with their diverse knowledge allowed us to gather a comprehensive overview of implementation and assessment of these important concepts on a national level and present Croatian know-how that can be used to advance environmental decision-making in the long term.

APPLICATION OF REMOTE SENSING PRODUCTS IN DETERMINING DAMAGE CAUSED BY A STORM

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KEYWORDS:
storm, remote sensing (LiDAR, RGB, IR), mapping of affected areas, measurement of parameters of individual trees, assessment of canopy damage

Nowadays, we are witnessing more and more frequent natural disasters (ice breaks, snow breaks, wind breaks, floods, fires, etc.), which affect forest ecosystems. The thunderstorm, which hit continental Croatia on July 19 and 21, 2023, caused huge material damage. The wind caused great damage to trees in forest stands, which can be divided by type into: fallen trees, broken, leaning trees, trees with partially or completely damaged or broken off canopy. Since we are dealing with large coverages with reduced or completely disabled access, the application of remote sensing methods is imposed as an extremely fast and reliable method. Since insight into the situation on the ground is needed in the shortest possible time, free satellite images are increasingly being used to locate stands affected by storms and to assess the wood stock of damaged trees. Due to their accuracy, simplicity of execution and speed, remote sensing methods are the unquestionable choice for damage assessment in comparison to terrestrial measurements. Today, when we have at our disposal unmanned aerial vehicles (drones) with various sensors, the images are available in everyday use at the operational level and as such are an indispensable choice when measuring parameters at the level of individual trees and stands (LiDAR), determining the extent and intensity of damage and monitoring the progress and success of rehabilitation (RGB and IR). The results of the interpretation (visual, digital, measurement) of various remote sensing products should contribute to solving numerous problems faced by forestry experts in the classic method of data collection, processing and analysis during natural disasters. Therefore, it is necessary to take advantage of the proven advantages of remote sensing methods, and this especially refers to the significant rationalization of field surveying while obtaining equally reliable data, and significantly reducing costs.

DYNAMICS OF ARTIFICIAL REGENERATION AND ESTABLISHMENT OF NEW FORESTS IN SERBIA FOR THE PERIOD 2017-2023

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KEYWORDS:
afforestation, private forests, restoration, state forests

Abstract: In the context of rising global temperatures and the escalating impacts of climate change, increasing the area under forest has become a critical task within forestry. This study aims to analyze the trends in afforestation over the past six years using statistical data, focusing on artificial regenration and establishment of new forests.

Analysis of available data reveals significant disparities between afforestation efforts in state-owned versus privately owned forests. In state-owned forests, afforestation with hardwoods is higher by 52.4% compared to conifers, and the largest number of used seedlings are oak (*Quercus* sp.), followed by poplars (*Populus* sp.), which are followed to a much smaller extent by black locust (*Robinia pseudoacacia*), other hardwood and softwood species, and finally beech (*Fagus sylvatica*). Among conifers, spruce (*Picea* sp.) and Austrian pine (*Pinus nigra*) dominate, followed by Scots pine (*Pinus sylvestris*), fir (*Abies alba*), Weymouth pine (*Pinus strobus*) and Douglas fir (*Pseudotsuga menziesii*) with a smaller number of seedlings. In private forests, conifers are afforested 15.6% more, spruce (*Picea* sp.) and Austrian pine (Pinus nigra L.) also dominate, while in hardwoods this role is taken over by poplar (*Populus* sp.) and black locust (*Robinia pseudoacacia*).

Year-over-year analysis demonstrates the varying extents and intensities of reforestation efforts, providing insights into the dynamic nature of these initiatives. These findings can inform more detailed analyses that support forest management plans, thereby contributing to enhanced afforestation strategies and subsequently expanding forested areas.

CLOSE-TO-NATURE FOREST SUSTAINABLE MANAGEMENT UNDER CLIMATE CHANGES - LIFE SYSTEMIC

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KEYWORDS:
biodiversity, forest genetic, GenBioSilvi model, silviculture, sustainable forest management

In 2018 the LIFE Programme, the EU's funding instrument for the environment and climate action, offered the opportunity to present projects that further develop and deepen the topic of forest monitoring by providing all the relevant data they can generate for current or future European forest information systems. In addition, it called for effective and efficient application of tools, methodologies, techniques, technologies and equipment to implement close-to-nature forest management approaches and similar silvicultural alternatives to more intensive forest management and/or management approaches based on planted even-aged and single-species stands. The impact of climate change on forest systems is recognised worldwide and its effects are increasingly visible in European forests. Nowhere is this more evident than in the Mediterranean region, where rising temperatures and the increasing frequency of extreme events such as storms, heatwaves and prolonged droughts pose a significant threat to forest ecosystems. These negative effects of new challenges for Sustainable Forest Management (SFM) required innovative approaches to protect and preserve forests as vital natural resources. Genetic diversity of forest tree populations has the crucial role in ability of forests to cope with climate change and other threats. Genetic diversity serves as the foundation for the long-term evolutionary processes that enable forests to maintain their adaptive potential in the face of environmental changes. In this context the LIFE SySTEMiC project is providing an important information and strategies for more effective conservation of genetic diversity of tree populations in forests. The general aim of the LIFE SySTEMiC project is to use the "tool" of genetic diversity to help our forests in times of climate changes. The basic idea is relatively simple: the higher the genetic diversity of the trees in forests, the more likely it is that some trees will have genetic characteristics that make them more adaptable to rapidly changing climate, thereby increasing the resilience of the forest ecosystem. Based on these premises, the main project objectives have been to:

1. Investigate the relationships between forest management and genetic diversity for eight forest tree species Croatia, Italy and Slovenia to identify the silvicultural systems that maintain high levels of genetic diversity.
2. Develop an innovative Genetic Biodiversity and Silvicultural model (GenBioSilvi) based on the combination of advanced landscape genomics, applied genetics, and silvicultural models to support SFM.
3. Disseminate of the knowledge about the method across Europe and to transfer its use in forestry practice by involving different types of stakeholders.

UNVEILING THE CULTURAL SIGNIFICANCE OF TRADITIONAL SHIFTING AGRICULTURE IN BIODIVERSITY CONSERVATION: PERSPECTIVES OF THE TANGKHUL COMMUNITY OF NORTHEAST INDIA

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KEYWORDS:
Agriculture, conservation, species richness, Tangkhul, traditional knowledge

In many tropical nations, shifting cultivation is a prevalent agricultural land use and widely recognised as practice that preserves high biodiversity levels along with chief food production system. The current study was conducted in Kamjong District of Manipur Northeast, India inhabited majorly by the Tangkhul and other communities like the Kukis, Nepalese and other non-tribal constitute a small percentage of the population. This study is aimed to firstly understand the shifting agricultural practices currently in used and secondly evaluate the recovery pattern of vegetation following shifting cultivation. This study employed a variety of methodologies, including focus group discussions, key informant interviews, and vegetation sampling by laying quadrats within different fallow period (5 years fallow, 10 years fallow, 15 years fallow and 20 years fallow) and a primary forest, followed by the enumeration and analysis of the plant species. The result showed that the species richness and diversity was recovered relatively with time within 15 years. The number of tree species increase by 6.89% from 5 years fallow to 10 years fallow, 9.67% from 10 years fallow to 15 years fallow and 8.82% from 15 years fallow to 20 years fallow. The findings of the study also showed that the Tangkhul traditional community has a profound awareness of changes in the seasons in order to ensure their survival. Furthermore, it illustrates how the indigenous groups of people in the mountainous Northeastern region of India have sustainably managed their landscape over generations through adapting to global change such as crop choices and agricultural practices. It must be acknowledged that within the confines of their current circumstances, traditional communities are responsibly adjusting to the ever-shifting environment. It is essential to work with communities to record traditional knowledge, long-term environmental change observations, and community-based resilience techniques. Integrating various knowledge systems into environmental policy-making will enhance understanding of how indigenous knowledge aids in conserving the biodiversity.

TISSUE CULTURE-MEDIATED REGENERATION AS A TOOL FOR SCALE-UP PROPAGATION OF SELECTED JAPANESE CONIFER TREES

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KEYWORDS:
Adventitious-buds, Cupressaceae, Micropropagation, Organogenesis, Somatic embryogenesis

Sugi (Japanese cedar, *Cryptomeria japonica D. Don*) and hinoki (Japanese cypress, *Chamaecyparis obtusa* Sieb. et Zucc.) are the most important conifer trees in Japan, covering 69% of the total artificial forest and accounting for approximately 7.1 million ha. In contrast to its commercial importance, actually, large amounts of pollen released from these forests each spring cause allergic reactions in approximately 40% of the population, being a serious social and public health problem in Japanese society. In this context, the use of pollen-free plants in reforestation is one of the most effective countermeasure against pollinosis. As one alternative, we develop an improved and simplified methodology for the efficient propagation of pollen-free plants of Japanese cedar, combining the use of genetic markers (marker-assisted selection) and the use of somatic embryogenesis for the clonal mass propagation of seedlings. Somatic embryogenesis is an excellent system for mass propagation, suitable for scale-up automation and artificial seed production, better for genetic transformation and genome editing, and ideal for cell biological studies. In addition, embryogenic cells can be cryopreserved for long-term without loss of juvenility, being a strong tool for preserving genetic materials in tree improvement programs. Despite the differences in response among embryogenic cell genotypes, the results of our experiments indicated that the potential for the production of somatic embryos in sugi and hinoki could exceed a thousand embryos per gram of embryogenic mass in fresh weight. Subsequently, high plantlet conversion frequencies (>80%) and high survival rate after ex vitro acclimatization (>70%) was achieved. Our results demonstrated that this methodology easily and efficiently produces plants in a short period and will definitively help to accelerate the scale-up production of somatic plants, as well as, basic studies on molecular biology and genetic improvement of both species. Additionally, propagation of hinoki through adventitious-buds multiplication was performed using adult-leaf-explants.

FEMALE STUDENTS' PERSPECTIVES ON FORESTRY CAREERS IN SERBIA

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KEYWORDS:
education, forestry career, gender, motivations, Serbia

The Interreg project Fem2forests (https://interreg-danube.eu/projects/fem2forests), which began in January 2024, involves 15 partners from 9 countries. It focuses on making the forestry sector more attractive to girls and young women by raising public awareness, increasing promotion and providing more opportunities for practical learning and mentoring. This paper aims to explore the perspectives, motivations and interests of female students in Serbia, identify the key factors influencing their decision to pursue a career in forestry, and highlight the challenges and barriers they face. Data collection was conducted in April 2024 using an online survey via the Google Forms platform. The study involved 105 participants, divided into two main groups: 1) 57 female forestry students (secondary schools and Faculty of Forestry); 2) 48 female students from other secondary schools and faculties. Love and passion for nature and the forest are the main motivation for pursuing forestry education for 51% forestry students. Also, 32% emphasized the importance of meaningful work and saw forestry as a way to have a positive impact on the environment and society. Environmental protection (58%) and forest ecology (39%) are of most interest to students wishing to study forestry. The results show a diverse spectrum of career aspirations among forestry students. The majority (60%) expressed an interest in nature conservation, while other popular career fields include forest management (32%), research (26%), climate change protection and mitigation (25%), urban forestry (25%) and sustainable forestry (21%). Notably, 92% of "other students" had not initially considered forestry as a career option, indicating a possible lack of awareness and exposure to the field. Only 17% of them were aware of career opportunities in forestry. The survey results provide valuable insights into the factors that could increase the attractiveness of forestry as a career choice among "other students": appropriate payment (67%), better image of foresters (42%), understanding, conserving and managing valuable natural resources (40%), etc. The biggest misconceptions/stereotypes about careers in forestry are: "it's not for women" (65% forestry and 54% other students), limited opportunities (49% forestry and 48% other students), "it doesn't require higher education" (44% forestry and 46% other students), low payment (32% forestry and 56% other students), "all foresters are lumberjacks" (51% forestry and 38% other students), etc. Raising awareness of the different aspects of forestry, improving public perception and providing more opportunities for hands-on learning are crucial steps to attract more young women to forestry careers in Serbia sector.

MYCORRHIZAL NETWORKING BETWEEN GRAPEVINE ROOTS IN BIOTIC STRESS CONTEXT: IMPACT ON PHYSIOLOGY OF HEALTHY GRAPEVINE

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KEYWORDS:
common mycorrhizal network, Rhizophagus irregularis, grapevine leafroll-associated virus 3, biotic stress

The majority of terrestrial plants engage in mycorrhizal symbiosis, which under field conditions often manifests as a common mycorrhizal network (CMN) that connects multiple plant hosts through mycorrhizal mycelium. This network facilitates the exchange of signals, nutrients, and water among its participants. Notably, the CMN has been shown to serve as a pathway for warning signals related to pests or pathogens. However, the role of CMN in linking virus-infected and virus-free hosts remains underexplored. To investigate this, we established a two-year greenhouse experiment to test the hypothesis that CMN between virus-infected and virus-free grapevines could serve as a pathway for virus warning signals. We utilized pots with two-compartments separated by a nylon mesh with a pore size of 30 µm, and placed "donor" plantlets in one compartment and "receiver" plantlets in the other. The "donor" plants were colonized by arbuscular mycorrhizal fungi (AMF) and/or infected with grapevine leafroll-associated virus 3 (GLRaV-3), while the "receiver" plants were free from both, resulting in four distinct combinations. The mesh prevented direct root contact but allowed AMF hyphae to pass through and establish a CMN. In this study, we examined the infuence of CMN on the growth parameters, photosynthesis rates, pigment levels, and elemental concentrations of the receiver plants over two consecutive years. The combinations of virus and AMF in the donor plants, along with the presence or absence of CMN, produced varying effects on the receivers. While the influence of the virus on the observed parameters was not pronounced, the impact of AMF and the presence of CMN was significantly stronger. Shoot length, carotenoid levels, and phosphorus concentrations in the leaves were most affected. These findings suggest that involvement in CMN may enable the transfer of different signals from virus-infected to virus-free grapevines, which could be reflected in growth dynamics, pigment levels, and phosphorus content in the leaves. Further analysis of the biochemical and molecular processes involved will provide deeper insights into the mechanisms activated in this complex interaction to discern if networking AMF feature can be additional reason to use these beneficial microbes as a sustainable biotechnological tool for avoiding virus-caused losses in viticulture.

TRENDS IN FOREST COVER BASED ON SENTINEL S2 IMAGERY IN PROTECTED AREA "TAJAN"

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KEYWORDS:
evergreen, deciduous, non-forest, gain-loss area prediction, random forest classification, 10 years' time-series

Identifying and monitoring changes in dominant categories of forest cover (evergreen, deciduous and non-forest) is important for forestry practice, especially in highly productive and protected areas with high ecological status. Today, remote sensing is a very accurate and practical tool for determining changes in forest cover at different scales. This work aimed to capture and detect trends in the dominant forest cover categories in the protected area – Natural Monument "Tajan", in central Bosnia and Herzegovina using available Sentinel S2 multispectral imagery data for a ten-year period, from 2015 to 2024. The classification was based on a random forest classification algorithm using 180 temporary sample plots (60 plots for each cover category) divided 70%:30% in training and evaluation subsets. The forest cover for evergreen and deciduous category and non-vegetation category were diverged and sequentially mapped. Then, trend analysis was performed using determined areas of investigated forest cover categories. Data processing was done using R packages. Modelling revealed classifications with an overall accuracy higher than 0.9 for each year. The significant trends in forest cover through the observed period are obtained: evergreen cover increases, deciduous cover decreases while non-forest areas remained stable with smaller gain-loos spatial fluctuation. The highest area increment in evergreen cover (decline in deciduous cover) is notified in beech and fir community (*Abieti-Fagetum*) (27.2%). The highest area increment in deciduous cover (decline in evergreen cover) is notified in black pine community (*Pinetum nigrae*) (12.3%). Results indicated spatial changes of non-forest cover with the highest gain in black and white pines community (*Pinetum nigrae-silvestris*). There, about 12.6% of non-forest cover at the beginning of the ten-year period changed to evergreen and deciduous covers, with 10.0% and 2.6% respectively. Additionally, the highest decrease in forest cover is present in the east-oriented highest mountain positions. The changes related to forest cover imply changes in overall stand conditions (forest tree layer, ground vegetation and soil organic layer). Areas related to deciduous cover decrease could indicate environmental changes affecting plant vitality with the decrease in species diversity as arising consequence. Obtained results could be used for the analysis of syndinamic and succession processes (decline/increase area with group or particular tree species) in relation with climate changes as well as for spatial determination of areas with raising deforestation indicating needs for urgent protection measures.

PLANNING GREEN INFRASTRUCTURE IN CROATIA: CURRENT STATE AND CHALLENGES

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KEYWORDS:
green infrastructure, strategic planning, green spaces, Croatia

Green and blue spaces are critical elements of urban environments, varying in proportion and distribution due to factors like topography, climate, and urban development. With the increasing visibility of climate change, the significance of these areas is becoming more recognised. They provide not only spaces for recreation and social interaction but also offer benefits such as air filtration, carbon sequestration, rainwater absorption, habitats for organisms, and educational opportunities about natural processes. These benefits are conceptualised as urban ecosystem services, which highlight the crucial role of nature in sustaining urban life. Despite being predominantly built environments; cities rely on these services for sustainability. Human impact on climate and biodiversity has reached global scales, influencing living conditions. Cities significantly affect these changes but also hold potential for efficient and environmentally friendly living. Ensuring widespread green and blue spaces in urban areas can mitigate air pollution, alleviate rainwater drainage pressure, create high-quality public spaces, and increase property values. The benefits are strongest locally but diminish with distance. This understanding has led to the development of the green infrastructure (GI) concept, which aims to create a network of green and blue spaces that provide localised and citywide synergistic effects. The European Union has recognised GI's importance for various policies. Promotion of GI development occurred in the 2014–2020 period, with increased investments in the current financial period (2021–2027). The European Commission defines GI as a strategically planned network of natural and semi-natural areas designed to provide ecosystem services, including green and blue spaces and other physical elements. In Croatia, GI planning is still developing, requiring greater sensitivity from city administrations. It started through seldom bottom-up initiatives in the late 2010s when city administrations asked for green infrastructure development strategies and continued through a national programme through which drafting green urban renewal strategies was financed. It is crucial to ensure participatory processes, which are still in infancy in Croatia. Participation in greenspace planning and management could foster ownership and responsibility for common spaces and transform public awareness about environmental care, influencing long-term political preferences. Finally, GI plans must be integrated into spatial planning documents if we are to create sustainable, resilient and pleasant cities for the 21st century. In this paper we present the progress in GI planning in Croatia, compare it with European practices and outline the weak points which need further focus and advancement.

LANDSCAPE ECOLOGY ANALYSIS OF THE KORENICA HUNTING GROUND

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KEYWORDS:
Landscape, landscape ecology, landscape planning, structure, application

Landscape ecology takes a holistic approach in viewing landscape as a heterogeneous whole, realizing that landscape is a complex system composed of mosaics of interdependent patches. It deals with interactions of induced human and natural spatial processes and processes within ecosystems. By observing these interactions, one obtains knowledge about the cause-andeffect relationships of natural and cultural landscapes, as well as the need for its protection and management. Landscape ecology has contributed to the understanding of structure, function and change of landscape over time- such structural understanding of landscape emphasizes the spatial heterogeneity and complexity of landscape as a functional unit. In this paper, an analysis of research area was conducted based on mapping and describing the structural ecological components of the landscape (matrix, patches, corridors). The analysis process was carried out through the following steps: (1) Collecting spatial data characteristic for determining the structural elements of the landscape for the research srea, (2) entering and analyzing the data and determining and classifying the structural components of the landscape according to the National Habitat Classification in GIS, (3) creating maps of the matrix, natural and anthropogenic patches, corridors, and a composite map, (4) describing the research area through individual structural components in the context of landscape ecology. The data used to define landscape structures are spatial data on habitats. The aim of the paper was to determine and explore the possibilities of applying the methods and principles of landscape ecology in landscape planning. Understanding the structure, function, causes, processes, and consequences of disturbances (both natural and anthropogenic) greatly contributes to professional and high-quality strategies and plans in the implementation of interventions or remediation protection procedures of existing ones. Knowledge of landscape ecology methods and principles plays a significant guiding role in landscape architecture— in planning and design procedures and processes, as they define new and/or existing landscapes that reflect social awareness and will dictate the environment, health, and future of all populations that inhabit them.

DAILY – SEASONAL ACTIVITY OF WILD CAT IN THE AREA OF PLIVITVIC LAKES NATIONAL PARK

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KEYWORDS:
wild cat, Plitvice Lakes, daily – seasonal activity, wild game

The wild cat (*Felis silvestris Schreber*, 1777) is a predator that belongs to the genus of small and medium-sized cats (Felis) within the cat family (Felidae). It has a relatively broad ecological valence and is spread from the Iberian Peninsula through central, southern and eastern Europe all the way to the Caucasus. It inhabits almost the entire territory of the Republic of Croatia, with the exception of the Adriatic islands. Since July 2013, the Croatian legislative framework has been adapted to European directives on strictly protected animal species, according to which the wild cat is a protected animal species with a year-round hunting ban. It is forbidden to hunt it in Armenia, Austria, Belgium, the Czech Republic, France, Germany, Greece, Hungary, Italy and some other European countries. Adoption of the legislative framework in many of the mentioned countries has no basis in scientific research work. Weak scientific research on wild cats in the territory of the Republic of Croatia was the reason for this research. In order to gain an insight into the daily - seasonal activity in the area of Plitvice Lakes National Park during the period 2023-2024, wild cat monitoring was established. The study included monitoring of activities on the entire surface of the park of approx. 30,000 ha. Activity was monitored through track recording, camera-traps, found carcasses and visual observations of live individuals. During the research period of two calendar years, the presence of a cat (photo of an individual, track, carcass) was recorded in 37 locations. The share of confirmed traces was in two cases, while only one dead individual was found during the research period. More than 39 500 photos/recorded events were examined and processed on the photo traps. Of all events recorded on cameras, less than 0.5% were events related to a wild cat. On the photo traps, 78% of recorded events related to cat activities were during reduced visibility, while only 22% were during daylight hours. Increased movement of the cat and more frequent activity at the monitoring locations was recorded in the period November - March, which is the period preceding mating, mating itself and a short period after mating. For the rest of the year, the cat was recorded on photo traps in passing without constantly visiting the location. During the monitoring, the presence of predatory and competitive species (wolf, lynx, bear, fox, jackal) was recorded. No statistical correlation between the activity of predatory and competitive species and the activity of the wild cat was found.

IDENTIFICATION OF LANDSCAPE VALUES OF THE MUNICIPALITY KAPTOL

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KEYWORDS:
Kaptol municipality, Papuk Nature Park, landscape values, identification, landscape preservation

The municipality of Kaptol is a local self-government unit located in the north-east of the Požega-Slavonia County. It includes 10 settlements and largely belongs to the area of the Papuk Nature Park. Due to its rich natural, cultural and visual-experiential value, it is necessary to properly protect, preserve and recognize this area. The first step towards the preservation and protection of an area is the identification of its values, which is also the fundamental method used in this work. After conducting cabinet research and fieldwork, this paper proceeded to process existing data and create new necessary data in GIS. The aim was to create a detailed database that would later be used for the identification of landscape elements in the municipality of Kaptol. The database was created from various sources containing already existing georeferenced data, but it was necessary to supplement them on several occasions as they were not fully or accurately produced. Analyzing the existing data, literature and cartographic representations and going out into the field, the landscape values of the selected scope were recognized and transformed into cartographic representations that show them in detail. This paper has shown that the studied area is rich in values that create a broad and significant potential for the development of many activities. The nature is pristine, rich in plant and animal species, watercourses, and features a diverse and extremely dynamic relief uncharacteristic for Slavonia. Even in ancient history, this area was recognized by people, as evidenced by numerous highly important archaeological sites. The visual qualities and specific mosaics of arable land are just some of the assets that give this municipality an advantage for progress. Landscape degradation is minimal, but there is noticeable neglect in environmental care in the form of illegal waste dumps, which are potentially the result of inadequate municipal waste management policies. This paper represents the starting point for evaluating the quality of the landscape, which aims to protect, preserve, and also develop the municipality of Kaptol.

ENHANCING FOREST MONITORING OF OAK FORESTS IN SOUTH-EAST EUROPE - OAKS

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KEYWORDS:
forest ecosystem functioning, vitality indicators, remote sensing, climate gradient

Since climate change is supposed to greatly influence the forest ecosystems in Europe, there is a great need for better forest monitoring that would encompass terrestrial and airborne techniques. This topic is also in the focus of the European Union, as evidenced from the Proposal for a new regulation for a monitoring framework for resilient European forests, where a comprehensive, high-quality forest monitoring system is envisaged to help counter new pressures and hazards. Existing monitoring schemes, such as UNECE ICP Forests, with its harmonised monitoring methodology, enhanced by additional, modern technologies can be a strong base for such a monitoring system.

The quantification of forest ecosystem behaviour in an environment changing in respect to climate is fundamental for future forest ecosystem goods and services maintenance, enhancement and restoration. In this context, it is important to determine the level of tree response to climate conditions by using indicators of tree vitality, such as crown defoliation, foliar nutrition, photosynthetic activity, or tree growth. Due to complex stand and ecological conditions, pedunculate oak forest ecosystems occupying large lowland areas in South-East Europe, are no longer as stable as they used to be.

Therefore, the objectives of the OAKS project are to:

- enhance the existing intensive monitoring on ICP Forests pedunculate oak plots in South-East Europe (Slovenia, Croatia and Serbia) in order to link water availability with tree growth
- perform parallel terrestrial and airborne measurements in the crowns of pedunculate oak trees to determine the relation of actual physiological data and vegetation indices acquired from multispectral images
- provide the ForestWard Observatory – a European observatory for forests climate change impacts of the FORWARDS project funded by EU - with near-real time data on tree growth in relation to weather conditions and soil water status for the duration of the project and additional 3 years.

For this purpose, the existing west-east climate/precipitation gradient in the form of three ICP Forests intensive monitoring plots, one in each country, is going to be utilised. Introducing new monitoring approaches into the existing ICP Forests system will open new research avenues for European forest monitoring. This type of multinational effort, realised through common in-field tasks, on a set of plots representing a strong climate gradient, represents a real innovation in forest monitoring.

Workshop 1

OPPORTUNITIES AND CONSTRAINTS OF FOREST RESTORATION AND PRESTORATION

MAINTAINING FOREST ECOSYSTEMS IN CLIMATE CHANGE BY ASSISTED MIGRATION: CONCEPTS, BENEFITS AND CHALLENGES FOR EUROPEAN FORESTRY

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KEYWORDS:
Climate change, reforestation, forest carbon sink, mitigation, adaptation

Climate change threatens major ecosystem services of European forests via increasing abiotic and biotic disturbances. These ecosystem services include, among others, the forest carbon sink which contributed continuously to the mitigation of climate change within past decades. Among the various adaptation measures to reduce the vulnerability of forests under future climate, assisted migration of tree species and seed provenances has been proposed. However, despite the growing evidence for increasing local forest tree dieback and population maladaption to future climate, European efforts for assisted migration are so far limited, partly due to heterogenous regulations and forest management concepts. Here, we introduce the first continent-wide analysis of assisted migration in European forests by identifying patterns of local adaptation in seven major trees species, modelling patterns for assisted migration and estimating the effect of assisted migartion on the Europeen forest carbon sink. Our study is based upon a dataset of 587 range-wide provenance trials, evaluating 2,964 provenances from their entire distribution. We found that to reduce forest vulnerability to climate change, coniferous trees need to be replaced by deciduous species over large parts of their distribution. However, if local seed sources are used for reforestation, we can expect a decrease of the current carbon sink (40 TgC yr–1) by 3441% until 20612080. If instead, seed sources adapted to future climates are used, the current carbon sinks could be maintained or even increased up to 4860 TgC yr–1. We discuss this findings in relation to current national and European legislation on forest reproductive material, on the need for further research and transnational cooperation to develop and implement AM and on the requirement to avoid unknown risks that might be connected with its large scale implementation.

RESTORATION NEEDS AND CONSTRAINTS IN THE REPUBLIC OF CROATIA

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KEYWORDS:
severe storms, forest loss, FRM, adaptation, resilience

European forests continuously face growing threats and pressures, which resulted with increase of both forest damages and restoration needs. Many European countries recognize the importance of achieving sustainable forest management goals, the necessity to increase forest resilience, as well as preserving and restoring forest biodiversity and ecosystem services. The reality of increased forest disturbances, backed up by elevated expectations from forests from a variety of different stakeholders, with newly acknowledged nature protection goals has altogether strongly added to the complexity of restoration issues. Thanks to its interesting geographical position in Southeast Europe, the Republic of Croatia possesses a high diversity of forest types and rich forests characterized by natural species composition (>98%). Nevertheless, forest practitioners are now faced with overbearing challenges while trying to meet restoration needs: from the low availability of forest seeds, insufficient production of forest seedlings, inadequate preparedness for extreme events, lack of knowledge and awareness on forest resilience, inadequate planning, shifts in site conditions to the insufficient dialogue among a variety of stakeholders and the lack of multidisciplinary approach to the forest restoration on the forest landscape level. The paper presents the most prominent challenges in restoration activities, which have emerged in Croatia in the last decade, focusing on the latest storm event in July 2023 which severely impacted the largest complex of pedunculate oak forest in Croatia (Spačva). Resources for effective and timely forest restoration are scarce so the need for effective collaboration between science and practical forestry, both on national and international levels is crucial, with effective action plans for fighting emerging challenges much needed. Thus, the paper will also address the biggest constraints in large-scale restoration efforts with the aim of proposing solutions and alleviating their effects.

RESTORATION OF PEDUNCULATE OAK STANDS – THE IMPORTANCE OF PROVENANCE SELECTION

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KEYWORDS:
climate changes, pedunculate oak, provenances, restoration, threats

Considering the presence of great variability of morphological and physiological characteristics of pedunculate oak provenances, research efforts on provenances have a significant role (Perić 2001). Long-term provenance tests, quite expensive and rare at the European level, provide the necessary background for making silviculture decisions in terms of provenance growth, production, vitality and consequently nursery production plans (Đodan and Perić 2023). Ongoing activities as part of the OKFŠ project: "Conservation of stands of pedunculate oak (*Quercus robur* L.) in the Republic of Croatia with an emphasis on biotic pests" financed by the Ministry of Agriculture of the Republic of Croatia have confirmed the importance of changing habitat conditions, and thus selection of adaptive provenances for the needs of regeneration and restoration of p. oak stands. The role of pedunculate oak restoration has increased expecially in the 2023 after severe storm hit Croatia. The goal of the research is to answer the question of whether there are significant differences in silvicultural features and production ability between provenances and localities. The research includes 16 provenances on two localities - Gajno (central Croatia) and Slavir (eastern Croatia). Provenances originate from natural distribution area of p. oak in the far east (provenance Mitrovica, Serbia) to those in the far west of Croatia (provenance Motovun). The experiment was set up in the spring of 1988, at both locations identically. Trees at the Slavir site were measured in winter/spring 2023, while trees in Gajno were measured in spring 2021 and 2023. All trees in the experiment were measured (tree height with Haglöf/Vertex IV and DBH with caliper) according to their unique number. The data was analyzed using the Statistica soft program. The analysis showed significant differences between the investigated provenances, both between localities and between provenances, which points to the conclusion that the selection of provenance must be based on scientific results since it plays a prominent role in the growth and development of p. oak stands.

PRESTORATION OF POPLAR PLANTATIONS WITHIN CROSS-BORDER COOPERATION OF CROATIA AND SERBIA

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KEYWORDS:
forest ecosystem, pedunculate oak, biodiversity, UPERB project, methodology

Increased occurrence of forest damages poses a threat to forest productivity and consequently decreases biomass and wood products production as well as complex impacts on the market. Moreover, damages can decrease ecosystem services and forest biodiversity. Anthropogenic influence, depopulation of areas, and lack of silvicultural measures, resources and manpower are some of the examples which significantly add to the restoration complexity and lower management options. Among its goals, the Green Deal SUPERB project tackles the influences of restoration activities on forest biodiversity. SUPERB project is carrying out restoration actions in 12 large-scale demonstration areas, one of which is the Border river floodplain demonstration area situated in Croatia and Serbia. Riparian forests play a crucial role in biodiversity conservation as they provide food and water resources to terrestrial and aquatic organisms, so the replacement of unmanaged poplar plantations presents a contribution not only to the diversity of forest products but to biodiversity and ecosystem services as well. SUPERB project activities aim to reverse habitat loss and degradation and increase forest resilience. The research presents activities initiated in the scope of the project on the Croatian part of the Border river floodplain demonstration area, which include monitoring of restoration activities conducted during the last three decades and initiation of prestoration activities on 50 ha. In order to successfully test forest restoration planting was carried out and the first results were recorded. Monitoring includes measurements of diameter at breast height, height of trees and tree-related microhabitats. A special methodology for project implementation and restoration success monitoring was adopted. The SUPERB project's adaptive restoration action in Croatia has revealed the complexity of restoration in a poor and depopulated area, which involves addressing stressors, necessary restoration measures, and legislation, all set against the backdrop of challenging socio-economic circumstances. Moreover, restoration and upscaling plans will be created and disseminated. Plans for upscaling forest restoration are crucial as they can help adapt to and mitigate climate change, help conserve biodiversity and improve ecosystems, while also providing economic benefits, improving human well-being and reducing poverty. By scaling up forest restoration efforts, we can help create a more sustainable future by sequestering more carbon dioxide, preventing forest loss and preserving natural habitats for countless species, ultimately contributing to global sustainability goals.

ESTABLISHMENT AND DEVELOPMENT OF LABORATORY FOR ADAPTED FOREST REPRODUCTIVE MATERIAL (LABADAPT)

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KEYWORDS:
Seedlings quality, biodiversity, nursery production, nature protection, sustainable forest management

Forest reproductive material (FRM) is crucial not only for forest regeneration but it is the backbone of diverse restoration and prestoration activities in forestry, nature protection, and beyond. Numerous pressures on forests, forest ecosystems and the forest sector are still growing, thus creating a gap between existing knowledge, awareness, readiness and resources and desired and needed ones. Recently, one of the crucial challenges is a lack of FRM, especially high-quality planting material adapted to future threats. A sufficient quantity and quality of FRM of properly selected species/provenance, with good resilience, and morphological and physiological characteristics is in significant shortage in Europe. Adapted FRM includes seeds, seedlings, cuttings, and naturally regenerated plants, better suited to the forthcoming climate changes, abiotic, biotic threats and socio-economic circumstances. Forests in Croatia provide various benefits from economic, social, and ecological perspectives (total of 77). Climate changes and invasive plant and animal species threaten the natural rejuvenation and development of forest species. This endangers the forest ecosystems, leading to a loss of biodiversity and individual species. Additionally, societal demands for products and services contribute to the instability of forest ecosystems. To preserve our forest habitat, it is crucial to cultivate high-quality forest seedlings that can withstand more frequent and intense threats, primarily climate extremes. A high-quality forest seedlings possesses morphological and physiological characteristics that enable better thriving and adapting to new environmental conditions. Individual morphological and physiological traits of seedlings alone cannot determine the success of planting in the field. Instead, the integration of different functional traits is necessary to predict success. At the end of the 20th century, over 30 methods were available for determining the quality of seedlings in the field, today only a certain number of properties are determined. To carry out the mentioned activities, and to avoid unnecessary losses (economic and biological), it is essential to establish a laboratory and to develop methods for growing and testing the quality of seedlings in Croatia. This will advance the science of silviculture, nature protection and agroforestry, improve expert supervision, and ensure the production of high-quality seedlings to meet the needs of the entire Republic of Croatia.

PEDUNCULATE OAK MANAGEMENT – CONTEMPORARY CHALLENGES AND RESTORATION CONSTRAINTS IN THE REPUBLIC OF CROATIA

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KEYWORDS:
nursery production, planning, degradation drivers, risks

Pedunculate oak (*Quercus robur* L.) is commercially the most important late successional tree species, with the largest natural distribution of all oaks in Europe. It forms mixed oak forests of prominent value from commercial (highly valuable veneer logs and timber) but also biological and social aspects (biodiversity and ecosystem services). Lately, numerous problems emerged in pedunculate oak management, especially problems with the availability of forest reproductive material and many constraints for efficient restoration of damaged stands. Shifts in site conditions add immensely to the complexity of contemporary silviculture, while increased climatic disturbances and social pressures quickly created a high need for restoration. The Republic of Croatia has recognized pedunculate oak as a backbone of its forestry already for centuries, so comprehensive insight into the history and contemporary challenges of pedunculate oak restoration in Croatia is a valuable contribution for the whole Europe, and beyond. The paper addresses pedunculate oak restoration needs and constraints with new data on prominent disturbances and their drivers in Croatia, with a highlight on large-scale storm event in July 2023. Knowledge exists, but resources for effective and timely restoration are scarce and the need for more collaboration between science, and practical forestry both on national and international levels is crucial, with effective action plans for fighting emerging challenges much needed.

Workshop 2

DEVELOPMENT OF NEW GENERATION OF SNACK FOOD FOR CONSUMERS WITH SPECIFIC DIETARY NEEDS USING 3D PRINTING TECHNOLOGIES ("3DSNACK4HEALTH", HRZZ-IP-2020-02-3829)

DEVELOPMENT OF 3D-PRINTED SNACKS FOR CONSUMERS WITH SPECIFIC DIETARY NEEDS

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KEYWORDS:
additive manufacturing, air-frying, cereal-based snacks, food by products, high intensity ultrasound

Food 3D printing has recently gained rising interest from reseachers and industry due to its advantages, particularly in customising food for specific dietary needs. The project *Development of New Generation of Snack Food for Consumers with Specific Dietary Needs using 3D Printing Technologies* (HRZZ-IP-2020-02-3829) has aimed to select ingredients based on chemical composition and rheological properties, to optimize the conditions of pre-processing, printing process, and post-processing of 3D-printed snacks having desirable sensory and textural properties intended for consumers with diabetes (DM), celiac disease (CD), non-allergy-non-celiac wheat sensitivity (NCWS) and irritable bowel syndrome (IBS), as well as to develop a prototype of custom-made extrusion-based 3D printer. The rheology of pastes was determined using an oscillatory rheometer. Physical properties and microstructure of printed raw and post-processed forms were evaluated by image, colour, and texture analysis or microscopy. Sensory attributes of snacks were assessed by a panel. Ingredients naturally high in fibre, without gluten and/or FODMAPs, and with fine particle size were selected: oat flour, pea protein, defatted flaxseeds, pumpkin seed cake, and wheat bran for DM, while buckwheat, millet and corn flour, chia, and rice protein isolates for CD, NCWS and IBS. FODMAPs (fructans and galactosaccharides) of wheat bran were hydrolysed with inulinase and invertase and/or fermentation with *Saccharomyces cerevisiae, Kluyveromyces marxianus, Lactobacillus fermentum* or LIVARNO® LV1 starter. Unlike pre-cooking, ultrasonication or bioprocessing with enzymes (glucose oxidase, xylanase and laccase) along with acidity regulators as well as the addition of hydrocolloids (xanthan, guar, sodium alginate, microcrystalline cellulose) improved dough rheology and printing precision, while prevented enzymatic browning and post-processing deformations. After optimising each recipe and 3D printing conditions (using response surfaces, least squares and artificial neural networks), pastes were accurately printed in various shapes (regular or irregular, with/without infill, 5-24 layers). Particular contribution was made in the post-processing techniques (conventional baking, oven drying, vacuum drying, air-frying at different temperatures) to preserve the designed shape while obtain the desired texture, colour, and flavour. Since lower post-processing temperature resulted in better physical quality, but poorer volatile profile, spices and commercial flavourings were applied directly to the paste for enhanced sensory acceptability. Overall, five types of savory and two types of sweet snacks with a balanced nutritive profile (ratio of protein, fat, carbohydrates and fibre) were created to meet specific dietary needs. A new 3D printer using the extrusion principle with compressed air was constructed, offering even better printing accuracy and precision.

HYDROCOLLOIDS AND ENZYMES APPLICATION FOR IMPROVEMENT OF 3D-PRINTABILITY AND STABILITY OF GLUTEN-FREE BATTER AND SNACKS

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KEYWORDS:
laccase, psyllium, post-processing deformation, print quality, xylanase

Hydrocolloids and enzymes are often used to improve the rheological properties of gluten-free batter but only a limited number of studies addressed their influence on 3D-printability and post-processing stability in case of gluten-free batter and snacks. The aim of this study was to compare the influence of enzymatic pre-processing of psyllium with laccase or xylanase with hydrocolloids addition (xanthan gum (X), sodium alginate (NaA), and microcrystalline cellulose (MCC)) on the printability and post-processing stability of millet-based gluten-free batter. Full-factorial (32) experimental design was used to investigate the effect of X, MCC and NaA at three addition levels (1, 2 and 3%, flour basis), and mixed-level (2x3) design was used to investigate the effect of psyllium with varying enzyme activity (0 U, 50 U and 100 U/g psyllium) and pH of batter (5 and 6). The control batter did not contain hydrocolloids nor psyllium. Rheological properties were measured with the frequency sweep using oscillatory rheometer (MCR92, Anton Paar, 25 mm plate system, 1 mm shear gap width). Foodbot D2 (Changxing Shiyin Technology Co., China) printed 20 layers of irregular closed shapes (0.84 mm nozzle), which were then post-processed in a drying oven for 30 min at 130°C. Shape printability and post-processing stability were evaluated using Image J software to analyse object photos. Pre-processing with all hydrocolloids increased the complex viscosity of the batter, but to varying degrees (X: 198-254%, NaA: 95-183%, MCC: 15-90%), whereas psyllium addition only slightly affected complex viscosity. Unlike with laccase, psyllium pre-processing with xylanase aided higher complex viscosity. The addition of hydrocolloids (particularly NaA) reduced the line and height deviations of the control batter from 16% and 12%, respectively, up to 1%. Hydrocolloids also minimized the diameter deviations of the control from 15% to ≤6.3%, while the diameter deviation of psyllium-containing batter was lessened to the same level with 50 U of xylanase. The control batter showed a drying deformation of 32%. Hydrocolloids reduced the drying deformation up to 7%, whereas psyllium and enzymes had negligible effect on post-processing stability. We can conclude that psyllium pre-processed with enzymes has potential for improving 3D printing of gluten-free batter, but is generally less effective in ensuring its stability than other hydrocolloids.

PROJECT 3Dsnack4health – WHAT WE NEED TO KNOW ABOUT 3D FOOD PRINTING?

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KEYWORDS:
3D food printing, processing parameters, snack, cereals

From the beginning of application of additive manufacturing in the production of food until today, new procedures, new 3D printers, new types of food that can be made, and new methods for post-processing have been developed. This all is the key to obtaining a quality food product. In order to be able to prepare a food mixture (such as chocolate (powder or liquid), cheese, dough with cereals and flour, meat puree, sugar, starch, powdered milk, pizza sauce, etc.) it is necessary to know the processing procedure and its production parameters (whether it is material extrusion, selective laser sintering, binder jetting or ink jetting). But when the requirements for a special diet are included in all of this (for example, people who have problems with celiac disease), rheological properties can be different for each mixture. Thus, as part of the 3Dsnack4health project, new 3D printer was development that will eliminate some errors on existing 3D printers for food printing in material extrusion process. So, first of all, it is necessary to prepare a snack with cereals of smaller granulations, because larger ones can cause the nozzle to clog, then it is necessary to know how the ingredients affect the rheological and mechanical properties, which is connected with a good choice of processing parameters (layer thickness, wall thickness, infill density, extrusion multiplier, nozzle temperature, manufacturing speed, retraction rate, etc). In addition, it is necessary to eliminate air inclusions that occur in the preparation of snacks and to choose an appropriate post-treatment for the final baking.

DESIGN AND FEATURES OF A 3D PRINTER FOR MAKING CEREAL SNACKS

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KEYWORDS:
3D printer, cereal, design, extrusion, food

Contemporary research in additive manufacturing makes it possible to expand the understanding of the production of 3D printed food. Machines conventionally used in polymer processing are redesigned for food extrusion purposes. In this work a 3D printer for paste like food materials is constructed and tested for printing snack products. The purpose of this device is to research the possibility of printing a cereal snack type food product for people with special nutritional needs. The printer movement is driven by belt and screw drive components which are assembled in a housing with an aluminum build plate. Vicotec printhead operating on a rotating positive displacement pump principle is chosen as extruder tool since it is suitable for highly viscous materials and allows a reverse direction of material flow. The extruder carriage is customized to connect to the printhead and material supply. Raspberry Pi electronics and stepper motor drives are combined to control the operation of the machine. Modifications of g-code generation have been made to change filament extrusion slicer for paste extrusion. The finished machine is fully functional and has various capabilities for parameter combinations making it ideal for research applications. Multiple models with a wide range of printing parameters are printed from paste type food material to test and confirm printer operation and reproducibility.

PREDICTING 3D PRINT SNACK QUALITY USING ARTIFICIAL NEURAL NETWORKS (ANN) AND RHEOLOGICAL DATA

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KEYWORDS:
ANN, rheology, 3D print, cereal snack

Artificial neural networks are computational models inspired by the biological neural networks of the human brain. They usually comprise of the input, hidden and output layers, and can be applied for research, development and industry purposes. They provide benefits such as adaptability, handling of large datasets and, being able to predict complex, nonlinear relationships. In 3D printing, ANNs present a promising method to be used to predict the relationship between the rheological properties of dough and the quality of the resulting 3D-printed products, which is often, non-linear. Rheological properties, such as viscosity, elasticity, and yield stress, are crucial determinants of how dough behaves during printing. In the project "3DSnack4Health" (IP-2020-3829) the potential of ANNs for predicting print quality parameters as outputs (print precision – line, heigt, diameter and shape deformation) using the rheological parameters of dough as inputs (complex viscosity, loss factor, yield stress, storage modulus and loss modulus) was explored. The most important rheological parameters of dough for the qualitative prediction of 3D printing quality of cereal-based snacks were defined.

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THE POTENTIAL OF USING GRAIN BY-PRODUCT IN THE DEVELOPMENT OF 3D-PRINTED SNACKS

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KEYWORDS:
3D-printing quality, baking deformation, complex viscosity, shelf-life, wheat bran

3D-printing is linked to sustainability in the food sector by enabling the use of alternative ingredients, such as grain by-products and plant-based proteins. This study aimed at developing both savory and sweet 3D-printed snacks formulations with grain by-products (wheat bran, defatted flaxseed flour, and pumpkin seed cake). The basic snack formulation consisted of oat flour, wheat bran, baking soda, glucose oxidase, and water. Savory snacks also contained pea protein, sunflower oil, salt, and either (1) pumpkin seed cake (SSP) or (2) defatted flaxseed flour (SSF), while sweet snacks incorporated rice protein and either (3) sugar (SWSS) or (4) honey (SWSH). Various 3D shapes (heart or quadratic with layer height of 0.4 mm and 20 or 5 layers, respectively) were extruded using the Createbot S3 printer. Shapes were baked at 180°C for 18 min for savory or 10 min for sweet snacks. Particle size distribution of ingredients (with laser diffraction method), dough rheology (using oscillatory amplitude and frequency sweep tests), printing quality (printing precision, shape accuracy and post-process deformation through digital image analysis), textural (cutting test) and colour (colorimeter) properties, and shelf-life were investigated. The peroxide value was monitored under ambient conditions in snacks with and without added pumpkin seed cake, stored in PPmet/PE bags for 30 days. Median diameters of 50th percentile ranged from 17.80 μm (rice proteins) to 993.16 μm (defatted flaxseed flour). All examined properties were significantly influenced by the dough mixture. Due to the largest G' (56948) and G'' (13104) values, SWSH was the most viscous dough. Savory snacks were more precisely printed (98% for SSP and 96% for SSF) and experienced less deformation during baking compared to sweetened dough. Savory snacks shrank (by -12 and -19%), whereas sweet snacks spread (by 52 and 70%). Snack deformation showed an inverse correlation (r=-0.85) with its hardness. Baked savory snacks were harder (2.47 to 2.84 g) compared to sweet snacks (0.63 to 0.78 g). The total colour change of investigated dough 1h after printing ranged from 1.43 to 1.86. Baked sweet snacks were significantly lighter and redder than savory snacks but exhibited higher browning index. Partial replacement of oat flour with pumpkin seed cake resulted in peroxide value of savory snacks over 10 after only one month of storage. Although dough containing grain by-products can be precisely 3D-printed into various shapes, special attention is needed to prevent undesirable post-process shape deformation and rapid oxidative spoilage of snacks.

POST-PROCESSING AND FLAVOURING EFFECTS ON QUALITY OF 3D GLUTEN-FREE SNACKS

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KEYWORDS:
air-frying, baking, oven-drying, vacuum-drying, sensory properties

Dimensional precision and accuracy are commonly used parameters to assess the quality of food 3D-printing; however, the behaviour of cereal-based inks during thermal post-processing is even more important since it significantly affects the final visual and organoleptic properties. This study aimed to investigate the influence of post-processing technique and the application of flavours on the quality of 3D-printed gluten-free snacks. 3D-printed gluten-free batter was composed of millet and sweet potato flour, rice protein and psyllium without or with added dry onion powder spice or onion powder flavouring. Batter was extrusion-printed into a 12-layer cloud shape without infill. Conventional baking, oven-drying, vacuum-drying, and air-frying combined with oven-drying were applied at 120°C and 160°C until reaching constant snack weight and water content (≤3%). Snack properties were instrumentally evaluated using digital image analysis, a texture analyser and a colorimeter as well as descriptive (0-10 scale) and hedonic (1-9 scale) sensory tests with twelve panellists. To reach the constant weight, vacuum-drying at 160°C required the shortest time (10 minutes) but caused the most shrinkage (43%), which was also noted by the sensory panel, whereas conventional baking at 120°C took the longest (35 minutes) but resulted in the least shrinkage (16%). Oven-dried samples at 120°C were the crunchiest (63 Nmm), whereas crunchiness was the lowest (19 Nmm) after conventional baking at 120°C. Hardness was highest after air-frying at 160°C (17 N) and lowest after vacuum-drying at 120°C (5.7 N). All techniques produced darker and redder samples at 160°C, so air-fried samples at 160°C were the darkest while samples were the lightest after conventional baking or vacuum-drying at 120°C. Additionally, air-frying at 160°C resulted in the highest intensity of burnt odour (3.08), roasted flavour (5.83), and sensory hardness (3.75), while these attributes were lowest after vacuum-drying (0.33, 2.91, 1.92, respectively). Hedonic analysis of appearance, odour, taste/flavour, and liking showed a slight preference for the samples processed at 120°C, with overall liking in range 5.4-6.6, i.e., lowest for the oven-dried and highest for the conventionally baked samples. Hence, lower temperatures are recommended for the post-processing of 3D-printed cereal-based snacks, whereby the choice of technique depends on the desired final properties. Onion powder spice and flavouring showed similar intensity of investigated sensory attributes as well as panellists' liking, but the addition of the flavouring to the snack oven dried at 120°C did not additionally increase the liking of the snack (6.5), indicating the need for further research in this area.

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