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I AGRICULTURAL ECONOMICS

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Water Quality, Climate Risks, and Institutional Barriers: A Comparative Analysis of Integrated Crop-Aquaculture Farming Systems in Bangladesh and Global Case Studies

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Abstract. Integrated crop-aquaculture systems (ICA) are considered a promising approach to enhancing food security and livelihood resilience in flood-prone regions. However, despite their potential, the widespread adoption and effectiveness of ICA in Bangladesh have been limited. This study investigates the barriers to the successful implementation of ICA systems in Rangpur, Kurigram, and Dinajpur, focusing on knowledge gaps, climate risks, and institutional support. Data were collected from 300 households practicing integrated farming using a mixed-methods approach, including surveys, water quality assessments, and interviews with local farmers and experts. The results indicate that over 60% of farmers lack formal training in essential aspects of ICA, such as water management and the integration of crops and fish. This lack of knowledge was found to correlate with a 20-30% reduction in productivity, both in crops and fish. Institutional barriers were also significant, with 72% of farmers reporting insufficient access to credit and agricultural extension services, further hindering the adoption of integrated practices. Global case studies from countries like Thailand and Vietnam, where ICA systems have been more successfully implemented, highlight the role of robust institutional support, farmer education, and accessible financial resources in enhancing both productivity and resilience. In contrast, Bangladesh's experience has been complicated by climate-related challenges, particularly flooding and erratic rainfall, leading to a 30% average decrease in farm productivity in flood-affected areas. Regression analysis quantifies the impact of these barriers, suggesting that improving farmer knowledge and access to credit could increase farm income by up to 35%, while strengthening institutional support could improve productivity by 18-22%. These findings emphasize that the successful adoption of ICA in Bangladesh is not only dependent on ecological suitability but also requires addressing critical knowledge gaps, institutional weaknesses, and climate risks. The research calls for policy interventions that focus on improving educational outreach, enhancing financial access, and strengthening institutional frameworks to support the sustainable implementation of integrated farming systems.

Keywords: Integrated Crop-Aquaculture, Water Quality, Climate Risks, Institutional Barriers, Food Security.

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A Longitudinal Comparative Analysis of Financial Sustainability in Estonian Dairy and Arable Crops Farms

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Abstract. Under increasing pressure on European agriculture, ensuring the financial sustainability of agricultural sector has become a key strategic objective. This paper analyses the long-term financial sustainability of Estonian agricultural enterprises over the period 2011–2023. The study aims to identify trends in profitability, liquidity, and stability across different types of agricultural enterprises, including cereals, oilseeds, and protein crops (COP) farms and dairy farms, providing insights to support both farm-level management and national policy-making. Data were obtained from the Farm Accountancy Data Network (FADN). Longitudinal trend analysis and correlation assessments were employed to examine temporal dynamics and sectoral differences. The results indicate differences between sectors in terms of financial stability and profitability, with dairy enterprises generally exhibiting higher stability, and crop enterprises showing more variable profitability. Liquidity appears generally adequate, and financial performance is closely linked to stability. At the same time, it must be acknowledged that without subsidies, the financial results of the sector would be unsatisfactory and the results within the production type would fluctuate widely from company to company. The longitudinal analysis of financial indicators offers valuable insights into sectoral strengths and vulnerabilities, demonstrating the usefulness of FADN-based assessments for monitoring agricultural financial sustainability and informing evidence-based policy and management decisions.

Keywords: agriculture, Estonia, FADN, financial sustainability, indicator.

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Valuation of Ecosystem Services for Climate Smart Agricultural Practices Using the Market Price Method

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Abstract. This study explores the monetary valuation of ecosystem services in Latvian agriculture, focusing on climate smart measures that reduce greenhouse gas (GHG) and ammonia (NH3) emissions and enhance carbon dioxide (CO_2) sequestration. Its core aim is to translate regulating and supporting ecosystem services into economic units that can be used for designing agricultural policy, managing farm, and planning sustainable land-use. The research applies the market price method, which links ecosystem functions to comparable market goods such as crop yields, raw materials, water volumes, and infrastructure costs. Although many ecosystem services are not directly traded, their benefits can be estimated using measurable biophysical indicators and market data. The methodology combines statistical analysis of GHG emissions (Eurostat and national data) with ecosystem service valuation formulas expressed in €/ha. Valuation examples include carbon sequestration, avoided yield loss from soil protection, increased yields from soil fertility measures, water regulation, timber provision, pollination, and recreation. Comparisons with the Ecosystem Services Valuation Database (ESVD) reveal that market-based values are generally lower, as they exclude indirect and long-term benefits like biodiversity and climate regulation. The study concludes that while the market price method is practical and policy-relevant, it captures only part of total ecosystem value and must be applied cautiously due to market fluctuations and contextual factors.

Keywords: Ecosystem services valuation, Climate-smart agricultural practices, Greenhouse gas and ammonia emission mitigation, Carbon sequestration in agricultural soils, Market-based valuation methods.

Acknowledgements. Latvia University of Life sciences and technologies.

II SAFEHABITUS FARM HEALTH AND SAFETY

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An Analysis of Romanian Mass Media Coverage of Work Accidents in Agriculture

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Abstract. Raising social awareness about existing risks is essential for improving health and safety policies in agricultural work. This article presents a systematic analysis of how workplace accidents in agriculture are reflected in Romanian mass media over a five-year period (2020-2024). Utilizing a specific social research approach, we examined all relevant articles identified through Google Advanced Search using a set of relevant keywords. Our analytical framework enables differentiation in media coverage based on the type of agricultural work, the nature of the accidents (fatal vs. non-fatal), and the causes and effects of these incidents when this are mentioned. We also explore the institutions mentioned in the news, the tone of the articles, and the voices referenced within them. This analysis is complemented by survey data assessing risk perceptions in agricultural work among the general population in Romania. By investigating how media narratives shape public perceptions of workplace safety and accountability, we underscore the interplay between reporting practices and societal attitudes toward agricultural labor. Our findings reveal that mass media not only reflects but also influences the discourse surrounding work-related injuries, enriching our understanding of cultural responsibility in agricultural contexts. Our research highlights the importance of informed societal dialogue in addressing the challenges of workplace safety in agriculture.

Keywords: Safety; Work-Accidents; Romania; Social Research; Mass-Media.

Acknowledgements. This research was conducted as part of the project ”Strengthening Farm Health and Safety Knowledge Innovation Systems” (SafeHabitus – GA 101084270), funded under Horizon Europe.

Root causes and wider consequences of threats to farmer health and safety: a cross-national socioecological analysis

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Abstract. Agriculture is one of Europe's most hazardous occupations, with farmers experiencing fatal accident rates significantly higher than most other sectors. Despite decades of safety interventions and regulatory frameworks, progress in reducing farm injuries and fatalities remains uneven across the EU. Understanding root causes and wider social consequences of farm safety challenges requires examining connections between immediate occupational risks and broader socioeconomic factors. Across 11 European Communities of Practice (CoP's) we conducted a Socioecological (SEM) examination of regionally prioritised safety challenges affecting key farming populations across 11 European countries. Participants included 65 experts on the specific safety challenges including farmers, advisors, safety experts, and policymakers. CoP's conducted Reflexive Thematic Analysis (RTA) on national data. A cross-national synthesis then identified common patterns of causes and consequences across socioecological levels, and shared themes across national data. Analysis revealed a hierarchical causal flow where policy and organisational-level decisions cascade downward to impact individual farmers' wellbeing. Consequences of these factors then further intensify the burden on individual organisations and farmers. Time poverty is the most widely shared factor across contexts by which these systemic pressures translate into and exacerbate safety risks. We identified four further themes illustrating how these causes and consequences happen across different domains. (1) Compliance-oriented regulatory cultures create implementation barriers, cause additional time for farmers and businesses, and drive non-compliance; (2) fragmented stakeholder coordination wastes resources, creates contradictory demands, and hampers long-term intervention effectiveness; (3) technology adoption can both alleviate and intensify time pressure depending on implementation, adoption, and education; and (4) gender and other group-based inequalities expose specific populations to high levels of occupational risk. These findings demonstrate that farm safety challenges are fundamentally structural problems exacerbating personal crises. We identify time poverty as a key theoretical lens to examine social and structural dimensions of farmers' wellbeing. Therefore, we recommend multi-level interventions are important to address root causes through policy and organisational-level changes, while interventions supporting on-farm behavioural change can help farmers cope with existing pressures.

Keywords: Agricultural Occupational Health, Farm Safety, Cross-cultural research, Socioecological Model Qualitative Synthesis.

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Working Conditions as Design Constraints in Climate Resilient EU Farming Systems

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Abstract. Agricultural biosystems in the EU increasingly operate under climate driven boundary conditions—heat exposure, erratic weather windows, and extended recovery periods following extreme events—that alter how people can work safely and reliably in the field. We treat working conditions not as external social outcomes but as core design constraints for climate resilient farming systems. Building on the SafeHabitus D4.4 multi actor process, we reinterpret occupational safety and health (OSH), labour recovery capacity, and social protection measures as system level parameters that shape the performance envelope of human in the loop agricultural operations. The evidence base comes from a two day, design oriented stakeholder workshop that combined rapid pair diagnostics, thematic clustering, prioritisation through voting, and roadmap co creation. Rather than focusing on policy narratives alone, we analyse the outputs through a biosystems engineering lens, examining how heat stress thresholds, task scheduling under climatic volatility, and access to short term relief or income stabilisation mechanisms affect the continuity, reliability, and adaptability of farm work. Across cases, climate change acts as a constraint multiplier—narrowing safe work windows (Pogačar et al., 2019; Morris et al., 2021), increasing psychosocial load (Lund et al., 2018; Becot et al., 2023), and reducing the headroom for young and self employed farmers to enter or remain in the sector. Research purpose was to determine how climate change reshapes working conditions and sector attractiveness, and to translate stakeholder identified challenges into system design requirements for climate resilient farming. Findings indicate that technical adaptation (e.g., climate smart agronomy, sensors, automation) improves resilience only when human factors are integrated into system design—for example, by embedding heat aware operating procedures, formal recovery and replacement services, and flexible income risk tools into standard workflows (Ma & Rahut, 2024). In practice, this requires specifying OSH criteria and labour support as design requirements, rather than post hoc mitigations, and aligning them with decision rules for shifting operations (night work, shaded tasks, work–rest cycles) during high risk periods. We conclude that future EU farming systems must be engineered as coupled human–technology–environment systems, where the attractiveness of farming emerges from reliable, safe, and economically buffered work processes. Treating OSH, social protection, and public understanding as enabling system components—rather than adjunct policies—creates actionable pathways to sustain labour capacity, retain young entrants, and stabilise system performance under climate stress.

References

1. Becot, F. A., Kohlbeck, S., & Ruszkowski, S. (2023). Investigating suicide in agriculture globally: A scoping review of methodological approaches and a roadmap for future research. Zenodo. https://doi.org/10.5281/zenodo.10406105
2. Lund, C., Brooke Sumner, C., Baingana, F., Baron, E. C., Breuer, E., Chandra, P., Saxena, S. (2018). Social determinants of mental disorders and the Sustainable Development Goals: A systematic review of reviews. The Lancet Psychiatry, 5(4), 357–369. https://doi.org/10.1016/S2215-0366(18)30060-9
3. Ma, W., & Rahut, D. B. (2024). Climate smart agriculture: Adoption, impacts, and implications for sustainable development. Mitigation and Adaptation Strategies for Global Change, 29, Article 44. https://doi.org/10.1007/s11027-024-10139-z
4. Morris, N. B., Levi, M., Morabito, M., Messeri, A., Nybo, L., Flouris, A. D., & Kjellstrom, T. (2021). Health versus wealth: Employer, employee and policymaker perspectives on occupational heat stress across multiple European industries. Temperature, 8(3), 284–301. https://doi.org/10.1080/23328940.2020.1852049
5. Pogačar, T., Casanueva, A., Kozjek, K., Ciuha, U., Mekjavic, I. B., Bogataj, L. K., & Črepinšek, Z. (2019). Heat waves occurrence and outdoor workers' self assessment of heat stress in Slovenia and Greece. International Journal of Environmental Research and Public Health, 16(4), 597. https://doi.org/10.3390/ijerph16040597
6. SafeHabitus (2025). Deliverable 4.4 – Anticipating pathways to the future of farming. SafeHabitus Deliverable 4.4 | Anticipating pathways to the future of farming | SafeHabitus

Keywords: occupational safety and health; labour recovery; working conditions; climate adaptation; EU agriculture.

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Medical Rehabilitation for Polish Farmers: System and Outcomes

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Abstract. In Poland, since 1992, the Agricultural Social Insurance Fund (KRUS) has implemented rehabilitation programs for farmers as part of its statutory mandate. The primary aim of medical rehabilitation is to restore the ability to work on a farm for individuals entitled to benefits under the farmers' social insurance system. Rehabilitation is intended both for those currently unable to work on a farm but with the potential to regain this ability through treatment, and for individuals at risk of permanently losing the capacity to perform agricultural work, as well as for beneficiaries of an agricultural pension. Over the past 30 years, the Fund's rehabilitation programs have developed substantially, offering farmers high-quality care based on recognized therapeutic methods and modern medical advancements. These services are delivered through the KRUS Farmers' Rehabilitation Centres, which have adapted their infrastructure and programs to meet the specific and demanding needs of this patient group. Strategically located in some of Poland's most attractive spa and health resort areas, these centres provide modern facilities and comprehensive medical services. Each centre specializes in rehabilitating musculoskeletal, cardiovascular, or respiratory conditions, often incorporating local natural resources, such as mineral waters or the therapeutic seaside climate. Patients receive individually tailored rehabilitation programs, benefiting from comfortable accommodations, therapy rooms, swimming pools, and recreational spaces. Currently, therapeutic rehabilitation for farmers consists of a 21-day inpatient stay, during which patients receive full board and a personalized program of 64 therapeutic procedures, averaging four treatments per day. Referrals for rehabilitation may be granted based on a final decision issued by a medical examiner or medical board during the assessment of social insurance benefits eligibility, or upon the request of an attending physician when the need for rehabilitation is clearly indicated. For pensioners, participation is granted exclusively upon a doctor's referral. In addition, the Fund organizes summer rehabilitation programs for farmers' children aged 7 to 15, primarily addressing musculoskeletal and respiratory conditions. Eligibility extends to children whose parent or legal guardian is covered by farmers' social insurance or receives an agricultural pension or disability pension. Each 21-day stay provides continuous medical care, with the program, scope, and number of treatments individually adapted to each child. Qualified staff supervises the children and organize additional educational and recreational activities outside of therapy sessions. Thanks to the Fund's initiatives, typically over 14,000 farmers and around 1,200 farmers' children have participated in medical rehabilitation each year. The COVID-19 pandemic caused a significant decline in these numbers, but since 2022, participation among farmers has been steadily increasing. Unfortunately, the number of farmers' children attending rehabilitation continues to decrease. In 2024, a total of 12,164 individuals benefited from rehabilitation services, with the majority being patients with musculoskeletal disorders (11,354), followed by those with cardiovascular conditions (810). That same year, 909 children also took part in rehabilitation programs. Overall, between 1992 and 2024, the Fund's rehabilitation services have reached 405,844 individuals, including 36,674 children. All rehabilitation costs are fully covered by the Fund, with total expenditure amounting to approximately EUR 13.2 million in 2024.

Keywords: medical rehabilitation, Polish farmers, KRUS (Agricultural Social Insurance Fund), occupational capacity, rehabilitation outcomes.

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Platformised Digital Agriculture and Technostress: Implications for Psychosocial Occupational Safety and Health

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Abstract. Digitalisation in agriculture is increasingly structured through platformisation: daily work is mediated by interconnected sensors, dashboards, notification pipelines, and vendor-governed service ecosystems. While automation and data-driven management can reduce physical workload and enable more flexible work organisation, platform-mediated arrangements may also increase psychosocial occupational safety and health (OSH) risks by reshaping temporality, interpretive responsibility, predictability, and practical agency. This article develops an explanatory platform-architecture account of technostress in digital agriculture through a theory-guided integrative review (narrative synthesis) using empirical "evidence anchors". From a prior systematic review corpus, we selected eleven scholarly sources (2004–2023) – primarily on automatic milking systems and related monitoring infrastructures – and synthesised recurring sociotechnical arrangements in welfare- and time-critical settings. The analysis yields a platform-architecture model linking work reorganisation to technostress appraisals clustered around four patterns: (1) availability pressures under always-on monitoring, (2) interpretive burden under opaque outputs and epistemic asymmetry, (3) constrained agency under proprietary service and update pathways, and (4) intensified self-evaluation under metricised dashboards. Framing technostress as an upstream outcome of platform-mediated work organisation clarifies why psychosocial OSH cannot be addressed through individual adaptation alone: risk depends on how platform design and governance allocate urgency, distribute uncertainty, and shape access to expertise, support, and repair. We therefore propose contestability – users' capacity to inspect, adjust, and stabilise platform mechanisms – as a practical mitigation principle for OSH-sensitive digitalisation.

Keywords: always-on monitoring; automatic milking systems; dashboards; epistemic asymmetry; monitoring infrastructures; platformisation; psychosocial OSH; service ecosystems; technostress; update governance.

Acknowledgements. This article was prepared as part of the Horizon Europe project, Strengthening Farm Health and Safety Knowledge and Innovation Systems (Contract number: 101084270; acronym: SafeHabitus; duration: 2023–2026), within the study 'Current and Future Drivers of Agricultural Change: Assessing the Implications for Working Conditions and Occupational Stress Amongst Farmers and Farm Workers' (2024) and as part of the national research programme Research on Mental Distress and Well-Being (P5-0115-23), co-funded by the Slovenian Research Agency (ARIS).

Applying Appreciative Inquiry in a Transnational Community of Practice: Insights from the SafeHabitus Project on Farm Health and Safety

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Abstract. Agriculture remains one of the most hazardous occupations in Europe, yet the effective sharing and adaptation of farm health and safety (FHS) good practices across diverse national contexts continues to be a challenge. This study investigates how the Appreciative Inquiry Model (AIM) can structure transnational Communities of Practice (CoP) dialogue to facilitate knowledge exchange, critical reflection, and contextual adaptation of FHS practices. A transnational CoP workshop was conducted with 25 representatives from 11 national CoPs. Data consisted of documentation of workshop discussions, participant feedback, and reflections from groupwork facilitators and SafeHabitus 'Super CoP' administrators. Thematic analysis was applied by multiple coders using a team-consensus approach, with validation by facilitators. Findings indicate that AIM effectively structured transnational CoP dialogue and created a positive, strengths-based environment for knowledge sharing. However, the model alone did not offer sufficient opportunity for critical reflection needed for context-sensitive adaptation. Where deeper analysis occurred, it resulted from the added "challenges" phase and the expertise of participants. Integrating explicit contextual-analysis tools, such as "if–then" transfer scenarios, and strengthening facilitator training would enhance the translation of shared practices into locally adapted interventions. The development and adaptation of good practices benefit from peer networks, but deeper co-creation requires time and skilled facilitation. While project-based networks can initiate transnational exchange, sustainable implementation of shared practices will require more stable, institutionalised CoPs that support ongoing knowledge sharing, critical reflection, and contextual adaptation.

Keywords: European agriculture, knowledge exchange, transnational learning.

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Who Is Protected? Governance patterns and coverage gaps in EU Farm Health and Safety across 11 EU member states

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Abstract. Agricultural work is shaped by separate policies with often competing priorities. Farming policies (e.g., CAP strategic plans) and worker protection frameworks (OSH) are usually developed independently. Consequently, key farming groups that do not fit traditional employment models are not included in policy. This study explored FHS policy (who is legally covered) and governance (how policy is designed, coordinated, implemented, and accountable) across 11 EU Member States to understand how governance shapes who is reached and protected by formal FHS systems. Within the SafeHabitus project, 11 EU states—Estonia, Finland, France, Germany, Ireland, Lithuania, Poland, Romania, Slovakia, Slovenia, and Spain—mapped their FHS policy and governance. Desk research and national Community of Practice and expert meetings identified key actors and developed actor maps using the Importance–Influence–Interest Matrix (IIM). These activities informed the guided evaluation through National Policy Dialogues (NPDs) examining (1) coordination (cross-sector collaboration, data sharing, multi-actor partnerships), (2) leadership (responsibility lines, defined roles, partnership mechanisms), and (3) farmer engagement in decision-making. Three governance patterns emerged from the preliminary comparative analysis:

• Integrated systems – typically stronger and more formalised coordination, with one or more agencies taking a recognised lead on FHS and structured advisory input and farmer participation, though the specific features vary by country.
• Network systems – active sectoral actors and advisory networks, but coordination is project-driven or temporary, and farmer engagement tends to be occasional.
• Fragmented systems – distributed responsibilities, weak coordination, and limited formal collaboration, resulting low farmer involvement.

Across all patterns, self-employed farmers, family labour, and seasonal or migrant workers remain only partly included in FHS governance. Self-employed farmers and family labour often fall outside standard worker protection regulations Seasonal and migrant workers are formally covered by OSH, but weak enforcement, unclear responsibilities, and precarious conditions limit real-world protection. In many countries, informal networks fill some of these gaps, but because they operate outside formal systems, their effectiveness varies and may unintentionally reinforce inequalities between farming groups. Farmer engagement with FHS is influenced by identity, cultural norms, and trusted relationships. More participatory approaches are therefore needed to ensure FHS policies are practical, relevant, and inclusive. Countries differ widely: some have structured opportunities for farmer input (e.g., advisory bodies, insurance committees, farmer organisations), while others rely more on informal networks or representative groups. These findings suggest structural rather than implementational limits in FHS governance. Three factors shape who is reached: (1) CAP, OSH, including FHS, are handled separately at EU level, creating a systemic gap which national systems cannot bridge; (2) current rules follow largely industrial employment models, while farming relies heavily on self employment, family labour, and informal work; and (3) informal networks provide support but have uneven reach and lack formality. These dynamics help explain why even well organised systems do not consistently reach all farm worker populations. All 11 countries have work-safety regulations: some general OSH rules and others farm-specific. However, regulation alone does not guarantee effective protection. Policy reach is limited by unclear responsibilities, weak cross-sector coordination, uneven advisory and inspection capacity, and limited data use to target risks. Findings suggest a 'governance void': FHS sits between agricultural and OHS policy. Agricultural policy focuses largely on production and sustainability, while OSH systems primarily cover employed workers. The size of this void differs: some countries link safety with advisory or insurance structures; others have minimal formal connections. At EU level, FHS is not an explicit CAP objective and is not fully addressed for non-standard farm work under OSH directives, leaving self-employed farmers and family labour without regulated protection. Strengthening participatory policy development and establishing a clear EU-level framework to connect agriculture and safety policies are essential for inclusive, practical governance reforms.

Keywords: Farm health and safety (FHS); Governance; Policy; Comparative analysis; Actor Mapping.
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Practical Advantages of East–West Oriented Vertical Bifacial Photovoltaic Systems for Enhancing Energy Autonomy in Agricultural Production

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Abstract. This study examines the practical advantages of using vertical bifacial photovoltaic (PV) modules with an East–West orientation in agricultural production. These systems provide peak electricity generation during morning and evening hours, when energy demand on farms is typically at its highest. It should be noted that their overall daily energy output is comparable to that of traditional South-oriented PV systems; however, the East–West generation profile more accurately matches the daily energy needs of agricultural facilities, reducing dependence on battery storage and lowering energy storage costs. The vertical configuration also allows installation in locations where conventional PV systems cannot be deployed, such as along fences, field boundaries, service roads, livestock building walls, greenhouse façades, and other spatially constrained areas. Consequently, East–West oriented vertical PV modules represent an efficient solution for improving the energy autonomy of agricultural enterprises. Moreover, combining these systems with classically oriented PV modules and other renewable heat and power technologies based on biomass conversion enables optimized energy supply in agriculture and supports the development of fully energy-autonomous farming operations.

Keywords: Photovoltaics, orientation, agricultural facilities, energy generation, sustainability.

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Integration Opportunities of Photovoltaic and Agrivoltaic Systems with the Energy Processes of the Prague Metro: Technical, Environmental and Operational Contexts

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Abstract. Growing demands for the decarbonisation of urban mobility and for more stable, decentralised energy systems highlight the need to identify new ways of effectively utilising renewable energy sources within densely populated urban environments. Prague is a city with a high level of energy consumption in public transport. In 2024, total electricity consumption reached 361 GWh, with the metro system being one of its largest continuous electricity consumers; traction operation alone accounted for 119.7 GWh. At the same time, the Prague Metro encompasses extensive technical and transport facilities that offer untapped potential for solar energy generation. The aim of this study is to analyse the possibilities of integrating photovoltaic (PV) and agrivoltaic systems with selected energy-related, climatic and technical processes associated with the operation of the Prague Metro, and to identify key benefits, limitations and opportunities for their practical implementation. The methodology includes a detailed identification of suitable locations for the installation of PV and agrivoltaic systems within the metro infrastructure, focusing on the roofs of operational and technological buildings, depots, garages, adjacent brownfields and other aboveground areas that enable the combined use of space for both energy and environmental functions. For these locations, an estimate of solar potential was carried out using basic radiation models, followed by a preliminary energy balance, an assessment of spatial conditions and modelling of expected energy yields. In parallel, the structure of the metro's electricity consumption—including traction, ventilation, lighting and technological systems—was analysed to assess the realistic share of renewable energy in covering these demands. The second part of the methodology addresses the technical and environmental aspects of underground transport in Prague that may influence the integration of renewable energy. This includes evaluating heat propagation and accumulation in tunnels, operational effects and ventilation regimes, interactions between train operations and their energy profiles, as well as the potential benefits of agrivoltaics, particularly for improving local microclimatic conditions, supporting biodiversity in adjacent areas and mitigating the urban heat island effect. Operational, safety and legislative requirements related to deploying PV systems on transport infrastructure were also taken into account. Preliminary results indicate that the selected locations provide considerable potential for meaningful energy contributions. PV installations could partially supply the energy consumption of operational buildings and certain auxiliary systems, while agrivoltaic applications could combine energy production with environmental benefits, particularly on larger technical areas such as depots, garages and parking facilities. Integration with metro operations also opens up opportunities for intelligent energy management, for example through storage systems or controlled charging of service vehicles. This study offers a new perspective on linking underground transport infrastructure with renewable energy sources in an urban environment and provides a foundation for developing practically feasible measures tailored to the conditions of the city of Prague. In the next phase, the results will be supplemented with detailed energy simulations and optimisation scenarios to support decision-making by the city and the transport authority.

Keywords: agro-photovoltaic systems, solar energy harvesting, urban transportation infrastructure, energy–mobility integration, sustainable metro systems.

IV WASTE RECOVERY

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The impact of different types of manure on the parameters of the composting process in a bioreactor

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Abstract. Composting has been practiced since ancient times, where it was used to enhance soil fertility and support crop production. It is therefore regarded as the oldest known method of biowaste treatment. Over time, the process has been systematically optimized through studies on the dynamics of aerobic biodegradation of various organic substrates, making it one of the most extensively investigated biological treatment technologies. Despite this long history, composting remains an important research topic, particularly in the context of circular economy strategies and sustainable development objectives. The aim of this study was to compare the composting dynamics of different types of manure. Experiments were conducted at the Ecotechnology Laboratory of the Poznań University of Life Sciences using four isothermal bioreactors (125 dm³ each) designed for controlled aerobic degradation. The tested materials included cattle manure (≈70% moisture), pig manure (>80%), a mixture of cattle and pig manure (≈65%), and cattle manure (>80%). During the process, O2 and CO2 concentrations, temperature, pH, bulk density, and mass loss were monitored, and dry matter, organic dry matter, organic carbon, and ash content were determined. The results showed clear differences in composting dynamics depending on manure type and moisture content. The cattle manure (70% moisture) exhibited rapid heating and a stable thermophilic phase, whereas highly moist pig manure showed slower temperature increase and lower intensity. The manure mixture demonstrated the highest microbiological activity, while excessive moisture in cattle manure (>80%) reduced process efficiency. These findings confirm that manure type and moisture are key determinants of composting performance.

Keywords: Composting process, compost, manure composting, bioreactor, physico-chemical changes.

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The influence of the composting process on changes in the physicochemical parameters of manure and ammonia emissions

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Abstract. With over 110 million tons of manure produced annually, Poland is the largest producer of this type of fertilizer in the European Union. Traditionally, storing manure in piles leads to significant greenhouse gas emissions (methane and nitrous oxide) and odors. It is also associated with significant nitrogen losses – primarily due to the high emissions of ammonia (which is not a greenhouse gas (GHG)) during manure storage, but also during its spreading on the field. Therefore, from an environmental (climate protection against GHG emissions), economic (reducing N losses), and social (reducing odor emissions) perspective, it is necessary to implement new, less harmful manure management systems. Alternative technologies to the traditional manure management method include anaerobic digestion and aerobic composting. Composting is a much cheaper technology, but it does not completely eliminate gaseous emissions. The aim of this study was to investigate the level of ammonia emissions resulting from manure composting (compared to the traditional method of storing manure in windrows) and to analyze the physicochemical changes in the composted material. To achieve this goal, a real-scale experiment was planned with four windrows of manure (P1-3: manure from dairy cows, P4 (pig manure) in the following variants: P1 - anaerobically stored pile; P2 - aerated pile with a tractor aerator; P3 - aerated pile with a tractor aerator and covered with a special rain-impermeable fabric; P4 - aerated pile with a tractor aerator (pig manure as a material with a higher nitrogen content). The test results indicated significant differences in all tested parameters between anaerobically stored (compacted) and composted manures. The maximum temperature of the P1 pile did not exceed 40°C, while all composted piles P2-P4 exceeded 65°C and exhibited a long-term (over 25 days) thermophilic phase. An increase in pH was noted in all piles, with the smallest increase in pH in the anaerobically stored manure. The smallest decrease in manure mass was also observed in pile P1 (only 11%), while in the composted piles a much greater mass loss was noted (P2-33%, P3-32%, P4-37%), which was primarily caused by intensive water evaporation due to the heating of the material during the composting process. This is confirmed by the results of the increase in dry matter content during the study, which was by far the lowest in the pile stored anaerobically, where evaporation was limited by material compaction to a level of 530 kg/m3. Ammonia emission studies showed that the highest ammonia emissions occurred from the composted open piles P4 (1520 g NH3/Mg d.m. – pig manure) and P2 (1230 g NH3/Mg d.m. – cattle manure). Cover-composted cattle manure generated the lowest emissions among the composted piles (1060 g NH3/Mg DM). As a result, a drastic decrease in ammonium nitrogen content was observed in all composted piles (P-2 90%, P-3 86%, P-4 80%) – however, this was not solely due to NH3 losses due to emissions, but rather to its conversion to organic nitrogen. This is confirmed by the results of changes in total nitrogen content, where maximum losses (calculated relative to the initial N-tot content) did not exceed 19%.

Keywords: farmyard manure, composting, ammonia emissions, physiochemical changes.

Reed- and straw-bale buildings: past and present. Studies in Estonia - minireview

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Abstract. The application of renewable resources for developing building materials should lower the carbon footprint of the construction industry. Reed was used as a construction material already by ancient societies, namely by Marsh Arabs and ancient Egyptians. It is generally known that straw-bale building technology was originally applied in Nebraska in the end of 1800s. More likely this technology may have occurred independently in different regions around the globe. Ancient societies, as Maya, Inca, and Aztecs, built their homes using grass and straw. Nowadays, straw- and reed-bale buildings perform rising popularity globally in accordance to their environmental and commercial features. In Estonia, a pioneering straw-bale house was completed only in 2002, indicating the start of an increasing trend toward the more intensive exploiting of natural building materials. 150 straw-bale houses have been completed in Estonia before 2025. The relevant research in this field has mainly been focused on the mechanical and physical properties of construction elements made from reed and straw, including compressive strength, thermal conductivity, and moisture resistance. Recent studies have been launched with the aim of examining indoor climate performance, which is closely linked to the microbiological conditions within these buildings. Proper design and maintenance are essential to prevent mold growth and ensure healthy indoor environments.

Keywords: ecological building, reed-bale building, straw-bale building, bio-based materials, sustainable construction.

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Upcycled agro-residue polyphenols as sustainable photoprotective UV filters

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Abstract. The skin is continuously exposed to ultraviolet (UV) radiation, which is a major environmental stressor contributing to oxidative damage, inflammation, photoageing, and the development of skin cancers. Although chemical UV filters are widely used in commercial sunscreens, increasing evidence points to their photoinstability, endocrine-disrupting potential, and ecotoxicity, prompting global calls for safer and more sustainable alternatives. Polyphenols naturally found in tea and coffee possess strong antioxidant, anti-inflammatory, and photoprotective properties, making them promising candidates for next-generation bioactive UV-protective ingredients. However, their potential remains underexploited, particularly in the case of food and beverage by-products that retain high phenolic content despite being treated as waste. In this study, tea and coffee processing residues are evaluated as low-cost, abundant, and renewable sources of bioactive polyphenols with UV-protective capabilities. Literature evidence demonstrates that catechins, chlorogenic acids, caffeic and ferulic acid derivatives can absorb UV radiation, neutralise reactive oxygen species, inhibit matrix metalloproteinases, reduce UV-induced inflammation, and support cellular defence pathways involved in DNA repair. By valorising agro-industrial waste streams, tea and coffee polyphenols offer a circular-economy approach to developing natural, multifunctional photoprotective ingredients. Harnessing these waste-derived polyphenols could contribute to the creation of safer and more sustainable UV-filter systems, while reducing environmental impact and supporting the transition toward greener skincare formulations.

Keywords: antioxidant activity; coffee polyphenols; natural UV filters; photoprotection; sustainable skincare; tea polyphenols; waste valorisation.

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V AGRICULTURAL ENGINEERING

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Assessment of plant nutrients losses during drying and granulation of poultry manure with straw and peat amendment

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Abstract. This study quantified nitrogen (N), phosphorus (P) and potassium (K) losses during poultry manure (PM) drying and granulation. Eight 2.0 kg samples were prepared: fresh PM (two samples), PM amended with 2.5%, 5.0% and 7.5% WS, and PM amended with 7.5%, 15.0% and 22.5% NP. Samples were dried to 25% moisture either at low temperature (24 °C) or using a combined regime of 1 h at 70 °C followed by drying at 24 °C. Granulation was performed using pellet press with 6 mm die openings, after which pellets were dried to 10–12% moisture. Raw materials and resulting pellets were analysed in a certified laboratory. Drying regime significantly affected nutrient retention. Losses from granulated pure PM dried at 24 °C were 18.1% (N) and 19.0% (P), whereas pre-drying for 1 h at 70 °C reduced losses to 7.2% (N) and 19.1% (P), corresponding to relative decreases of 60.2% (N) and 52.2% (P) compared with low-temperature drying. The highest nutrient losses occurred in pellets from the PM95+WS5 mixture, where N and P contents decreased by 18.1% and 10.9%, respectively. No N losses were detected in pellets produced with 7.5% or 15% NP, and no P losses in pellets with 15% NP15. Straw or peat additions prevented K losses and slightly increased K concentrations in the pellets, likely due to the removal of sand in drying-granulation. Results demonstrate that WS7.5% and NP15% amendments effectively mitigate nutrient losses during low-temperature drying–granulation, while high-temperature pre-drying markedly enhances nutrient retention by limiting microbial degradation.

Keywords: granules, nitrogen, organic fertilisers, phosphorus, poultry manure.

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Study of the crumpling conditions of carrot top residues on the root crown under impact contact of a cleaning blade and determination of the mass of removed residues

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Abstract. The aim of this study was to estimate the mass ( ) of carrot top residues removed from the root crown by a flexible cleaning blade after impact contact, and to analyse the sensitivity of the model to the kinematic and design parameters of the cleaner. The study combined a criterion for residue weakening during impact with a simplified model of post-impact removing. Literature data on carrot crown geometry and crop mechanical properties were used together with the design parameters of a two-shaft cleaner. The developed model was analysed for ω = 10–50 rad s–1, ρ = 0.06–0.12 m, b = 0.03–0.06 m and = 0.002–0.005 m. Because values of the effective bulk density of the compacted top-residue layer and its thickness after impact were not found in the literature, = 850 kg m–3 and = 0.008 s were assumed for modelling, whereas was varied within an engineering range. At the initial values ω = 30 rad s–1, ρ = 0.10 m, b = 0.04 m and = 0.004 m, the mass removed per blade pass equals 3.264 g. The constructed response surfaces showed a monotonic increase of with all variables; within the selected limits, reaches 0.65–6.53 g for the pair (ω, ρ) and 1.22–6.12 g for the pair (b,). The calculated initial residue mass on the carrot crown of 13.86 g indicates that a blade pass can remove about 23.5% of the nominal load, supporting the use of multi-blade cleaners and two parallel shafts.

Keywords: coefficient of restitution, elastic blade, kinematic parameters, post-impact removing, response surface analysis, two-shaft cleaner.

Study of finger-star disc working tools of an inter-row cultivator

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Abstract. The study reports laboratory and field investigations of an inter-row cultivator equipped with polyurethane finger-star discs intended for gentle uprooting of weeds in transplanted tomato rows. The aim was to determine technical and process indicators, obtain force-deflection characteristics for different Shore A hardness values, and assess the risk of crop damage by comparing finger bending forces with tomato transplant pull-out forces. Tests were conducted at a working width of 4.2 m, travel speed of 1.0–2.0 m s–1, cultivation depth of 1.5–5.0 cm for elastic discs; length of polyurethane fingers 250 mm and finger inclination angle 54 deg. Weed destruction (lambsquarters, pigweed and foxtail) at the “white-thread” stage reached 100% and no injury to established plants was observed. Laboratory measurements with an AXIS FB2k dynamometer provided force-deflection relationships for hardness values of 73, 83 and 93 Shore A. Field measurements showed that the pull-out force of tomato transplants at soil moisture contents of 10% and 18% in the 0–100 mm layer substantially exceeded the bending forces of polyurethane fingers. Therefore, hardness values of 73, 83 and 93 Shore A are recommended for crops with pull-out forces of at least 10, 15 and 25 N, respectively. A theoretical analysis based on the Euler-Bernoulli cantilever-beam model was used to formulate conditions for weed sweeping while avoiding crop damage.

Keywords: cantilever-beam model, elastic deformation, inter-row cultivation, pull-out force, polyurethane, rotary weeding, Shore A hardness, tomato transplants, weed uprooting, white-thread stage.

Development of naturally ventilated solar energy assisted maize seed store

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Abstract. This abstract presents a study on enhancing maize seed storage in Cameroon by developing a naturally-ventilated solar-assisted store. The study designed a 22-m³ store using a chimney and a solar collector, which reduced relative humidity to 40.1% and maintained a 98.5% germination rate over three months, significantly outperforming control storage (96.8%). The seed industry in Cameroon faces significant storage losses, with poor ventilation leading to reduced viability and fungal development, compromising food security. To design, construct, and evaluate a naturally-ventilated, solar energy-assisted maize seed storage room to optimize storage conditions without relying solely on expensive active cooling systems. A 22-m³ room was retrofitted with a chimney and solar collector. Four chimney sizes (diameter, height) were evaluated to optimize air ventilation. Parameters such as air temperature, relative humidity, and air velocity were recorded. The modified room was tested against a control room (unmodified) for three months, monitoring seed germination, moisture content, and vigour. The optimized chimney) significantly enhanced performance. The modified store achieved a lower average relative humidity, compared to the control. Maize seeds stored in the modified room showed a significantly higher germination percentage compared to the control over three months. The naturally-ventilated solar energy-assisted seed storage room effectively reduces storage humidity and preserves maize seed quality, offering a sustainable, low-cost solution for smallholder farmers.

Keywords: Maize, Chimney, Energy, Solar, Sustainable.

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Impact of Brassicaceae intercrops on fuel consumption, energy and GHG indices in maize cultivation

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Abstract. Multicrops can improve energy use and reduce GHG balance problems, but the development and productivity of such mixed crops are at risk due to concurrence between agroecosystem components. For this reason, investigations were performed at the Experimental Station of Vytautas Magnus University, Lithuania. Single maize crop was compared with white mustard, spring oilseed rape, oilseed radish and spring Camelina. Calculations showed that the least fuel was consumed when using the single maize growing technology, as the rows were loosened without other energy-consuming operations. When mulching the maize rows with weeds, fuel consumption increased by about 3.5 l ha-1, and when sowing with intercrops, it increased by about 12 l ha-1. 2025 was not favorable for the development of maize. They produced only about a quarter to a third of the biomass produced in favorable years. It was highest of the single maize crop and maize+mustard technologies. The most NET energy was captured in the technology with mustard intercropping - 203072.7 MJ ha-1. All tested technologies were environmentally friendly; CO2 equivalent varied between treatments from 608 to 688 kg ha-1. The most environmentally friendly technology was interrow cutting and mulching with weeds. This treatment is related to permaculture farming.

Keywords: Zea mays L.; companions; fuel; energy; CO_2 equivalent.

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Compilation of a dynamic model of a remotely controlled mobile robot chassis and dynamic parameter study of its 18V DC electric motor

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Abstract. This study focuses on the development of a dynamic mathematical model for a remotely controlled mobile robot chassis prototype, built at Kaunas College, and presents an experimental analysis of its 18V DC motor dynamic parameters. The methodology combines the mathematical modelling of chassis motion with experimental testing of motor behavior under both no-load and full-load conditions. The experimental results reveal a significant difference in motor requirements between operating states. Specifically, overcoming static friction under load requires a start-up voltage of 5.51 V and a current of 6 A, corresponding to 33.06 W of power. The developed dynamic model, validated by the obtained experimental data, allows for a more accurate prediction of the robot's motion trajectory and provides crucial insights into the motor power requirements necessary for stable initiation of movement under loaded conditions.

Keywords: motor, chassis, model, dynamics, prototype.

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VI BIOENERGY AND BIOFUELS

From Waste to Resource: Torrefaction Condensate as a Feedstock for Microalgal EPS Production

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Abstract. Torrefaction produces torrefied biomass, non-condensable gases, and condensable gases. The latter produces an acid-rich liquid known as torrefaction condensate (TC). In this study, TC derived from Aspen wood pellets torrefied at different temperatures was characterised, and the 225 °C torrefied TC was evaluated for its effect on the growth and exopolysaccharide (EPS) production of the microalgae Chlamydomonas reinharditii. Exposure to TC at concentrations of 2.0–2.5 mL/L initially inhibited algal growth, EPS synthesis, and altered biochemical composition, including amino acids, lipids, and fatty acids. However, the culture demonstrated adaptive capacity over time, eventually reaching growth patterns comparable to the control. The biochemical profile and antioxidant activity of EPS produced under TC exposure differed significantly from those of the control. These results demonstrate that, although inhibitory at early stages, TC can be utilised as a low-cost substrate for microalgal cultivation. This approach supports the integration of torrefaction by-products into microalgal biorefineries, contributing to circular bioeconomy strategies by producing value-added compounds such as EPS.

Keywords: Green algae, thermochemical conversion process, antioxidant assays, fatty acids, and amino acids.

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Towards the modeling of twin-screw extrusion for the biorefinery of lignocellulosic biomass and the production of agromaterials

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Abstract. Due to its ability to provide intense, continuous thermo-mechanical treatment to concentrated materials, and its low effluent production, twin-screw extrusion is a process frequently encountered in biorefineries. It can be applied to a wide range of raw materials, including the structuring of bio-composite materials (Uitterhaegen et al., 2018), the refining of biomass by Liquid/Solid (L/S) fractionation (Li et al., 2022), and the extraction of biopolymers of interest from agri-food waste (Ralet et al., 1993). Its potential as a continuous L/S extractor has been demonstrated on machines of different sizes to cover throughput ranges from 1 to 200 kg/h of dry matter, while valuing the two fractions generated: the filtrate (liquid extract), as biomolecules for various fields (food, energy, cosmetics, etc.) and the extrudate (residual solid fraction rich in fibers), for the shaping of agromaterials (Evon et al., 2018; Vandenbossche et al., 2019). Due to the complexity of the raw materials and the lack of understanding of the mechanisms involved, it is difficult to predict the output variables (O: specific mechanical energy, pressure drop, material temperature, etc.) based on the input ones (I : raw material properties, operating conditions, and extruder configuration), and, a fortiori, to relate those to quality attributes, which are specific to each application. Consequently, the use of twin-screw extrusion and the development of applications in biorefineries rely heavily on the knowledge and expertise of research teams. These approaches are primarily based on empirical observations in industrial settings. Besides, an approach based on a 1D flow model of biopolymer-based material, considered as a homogeneous viscous fluid within a twin-screw extruder, provides good predictions of the physical variables (or O variables) governing its transformation, provided its rheological behavior is properly described (Berzin et al., 2010). The quality of the extruded material can then be predicted if relationships between its defining properties and the I variables have been previously established, as in the case of cereal products and legumes (Kristiawan et al., 2022), or cellulose nanofibrils (Rol et al., 2020). After reviewing the possibilities offered by this process in biorefineries, this presentation will attempt to demonstrate the underlying assumptions to test this simple mechanical model in order to establish its relevance for various applications involving heterogeneous media, and thus to identify the knowledge gaps that limit its use as a tool for predicting the quality of extruded products in biorefineries. Ultimately, the aim is to propose a generic approach, by extending the initial model to the L/S fractionation of lignocellulosic biomass in twin-screw extrusion.

References

Berzin, F., Tara, A., Tighzert, L. and Vergnes, B., 2010, Importance of Coupling Between Specific Energy and Viscosity in the Modeling of Twin Screw Extrusion of Starchy Products, Pol.Eng. Sci., 50: 1758-66, DOI 10.1002/pen.21702

Evon, Ph., Vandenbossche, V., Candy, L., Pontalier, P.Y. and Rouilly, A., Twin-screw extrusion: a key technology for the biorefinery. Biomass extrusion and reaction technologies: principles to practices and future potential (1st Edition), American Chemical Society, ACS Symposium Series, eBooks, Ayoub, A. and Lucia, L.Eds, 2018, pp 25-44.

Kristiawan, M., Della Valle, G. and Berzin, F., 2022, Extrusion simulation for the design of cereal and legumes foods. Foods Special Issue «Food Rheology and Applications in Food Product Design », 11, 1780. https://doi.org/10.3390/foods11121780

Li, J., Evon, Ph., Ballas, S., Khai Trinh, H., Xu, L., Van Poucke, C., Van Drogenbroeck, B., Motti, P., Mangelinckx, S., Ramirez, A., Van Gerrewey, T. and Geelen, D., 2022, Sunflower Bark Extract as a Biostimulant Suppresses Reactive Oxygen Species in Salt-Stressed Arabidopsis, Frontiers in Plant Science - Plant Abiotic Stress, 13: 837441, DOI10.3389/fpls.2022.837441

Ralet, M-C., Della Valle, G. and Thibault, J-F., 1993, Raw and extruded fibre from pea hulls, Carb. Polymers 20: 17-23, DOI10.1016/0144-8617(93)90028-

Rol, F., Vergnes, B., El Kissi, N. and Bras, J., 2020, Nanocellulose Production by Twin-Screw Extrusion:Simulation of the Screw Profile To Increase the Productivity, ACS Sustainable Chem. Eng., 8: 50−59, DOI: 10.1021/acssuschemeng.9b01913

Uitterhaegen, E., Burianová, K., Ballas, S., Véronèse, T., Merah, O., Talou, T., Stevens, C.V., Evon, Ph. and Simon, V., 2018, Characterization of volatile organic compound emissions from self-bonded boards resulting from a coriander biorefinery, Industrial Crops and Products, 122: 57-65, doi.org/10.1016/j.indcrop.2018.05.050

Vandenbossche, V., Candy, L., Evon, Ph., Rouilly, A. and Pontalier, P.Y., Green Food Processing Techniques: Preservation, Transformation and Extraction, Elsevier, Chemat, F. and Vorobiev, E. Eds, 2019, pp. 289-314.

Keywords: Filter, Mechanical model, Liquid-solid, Quality, Rheology.

Sustainability crisis and our responsibility as scientific community

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Abstract. The climate and sustainability crisis is humanity's greatest challenge, with increasingly frequent droughts, wildfires, floods, and storms signaling breached planetary boundaries and imminent tipping points. Despite clear evidence from scientific research and everyday experiences, greenhouse gas emissions continue to rise exponentially due to political, societal, and individual barriers. Given its systemic nature, the sustainability crisis cannot be addressed through technological progress alone but requires a complete paradigm shift. As scientists, we bear a special responsibility to lead the communication of the urgent need for action to both the public and decision-makers. Recently, we founded the International Alliance of Societies for a Sustainable Future (https://sfs-alliance.org). Motivated by the fragility of existing political networks, our vision is to leverage the robust and stable international scientific network to alert the global public about the sustainability crisis and recommend measures for socio-ecological transformation. This alliance spans all disciplines across borders and cultures.

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Process lines for paludi-biomass from rewetted peatland

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Abstract. Europe is covered by 60 Mha peatland. A large share of this land is drained for agriculture, resulting in fast degradation of organic soil matter and the release of large amounts of greenhouse gases (10 - 30 t CO2eq.ha-1yr-1). Taking Germany alone this agricultural practice is connected to annual emission of 53 million t CO2eq. In order to activate this high CO2 saving potential in the short term, a cooperative transformation of peatland management together with land users is a core target of current climate policy in Germany. The development of innovative grass-based value chains providing alternative income for farmer working on rewetted peatland is needed as soon as possible. Therefore, several research projects have been started in the last years in Germany, among these biorefinery focused projects at the Leibniz Institute for Agricultural Engineering and bioeconomy (ATB). The target of these projects is the development of grass based process lines e.g. for pulp and paper or building materials. A pilot biorefinery has been developed together with partners from industry, first prototypes have been successfully produced and are further investigated. The presentation aims to provide information of the raw material, introduce steps of the developed processing line, and shows intermediate and end products manufactured. The presentation of the processing line will include results on the use of a twin-screw extruder, which is the main machine in the thermo-mechanical defibration process of the paludi biomass. The processing line for paludi-biomass can be used for other lignocellulosic plant material too.

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The concept of energy management of sawmill waste – economic and environmental effects

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Abstract. The aim of this study was to develop a concept for the energy management of waste generated by a selected sawmill, for the purpose of wood drying at the plant. The plant produces various wood waste products (chips, edgings, sawdust), with a total volume of 3000 m3. About 960 m³ of boards are dried annually in the drying plant, which uses electricity. Assuming the energy demand for drying 1 m³ of wood is 150 kWh, the annual energy consumption was calculated to be 144 MWh. A proposal was made to modernize the wood drying facility, utilizing sawmill waste. Laboratory tests were conducted on individual types of waste, in accordance with applicable biomass standards. Based on this, the energy yield of the entire waste mass was calculated. The drying facility was planned to be equipped with a boiler adapted to biomass combustion, equipped with a gas post-combustion chamber, which is recommended for biomass combustion. After shredding, wood waste will be fed to the boiler using an automatically controlled feeder, reducing the labor required to load the container. The costs and emissions associated with current drying using electricity were compared with the proposed concept of using the company's own wood waste. The payback period for the biomass boiler plant and its equipment would be approximately two years. Annual reductions in atmospheric pollutant emissions were also calculated: 105.55 Mg CO2, 64.08 kg SOx, 69.26 kg NOx, 39.31 kg CO, and 2.59 kg of total particulate matter.

Keywords: biomass, emission reduction, sawmill, wood wastes.

Acknowledgements. The research was carried out as part of the Scientific and Research Subsidy of the University of Life Sciences in Lublin SUBB.WTD.25.015 IŚGiE.

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Transforming Hop harvest waste into valuable fibers: A study on wet storage and wet processing of the biomass

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Abstract. Hop (Humulus lupulus L.), a perennial climber plant, has a significant agricultural and industrial presence, primarily valued for its cones in the beer brewing industry. In case of Germany, the area of cultivation accounted nearly 20,300 hectares and total estimate of hop cones harvested in the five German hop-growing regions was approximately 46,500 tons in the year 2024. Hop residual biomass has been identified as a potential bast fiber source, comprising phloem (bast) fibers and woody core, similar to flax and hemp. In contrast, this potential resource with an annual amount of up to 100,000 tons alone in Germany has largely gone untapped to date. It's use as a feedstock for bio-methanization is very limited, as is the use of the resulting compost as fertilizer. On the other hand, material utilization of such agricultural residues can contribute as an extension or even as an alternative for fiber production in certain extent. Environmental degradation, strict environmental protection policies and overexploitation of fossil, beside others, fuels hints necessity of alternatives. As part of a collaborative project, research is currently being carried out into how hop stalk residual biomass can be stored and processed whilst maintaining its quality, and how the resulting fibers can be used as filling or even reinforcing materials in plastics. Once the cones have been picked from the harvested crop, the biomass has a comparable high-water content. As there is a lack of drying capacity at this time, wet preservation (silage) is the preferred method of storage. The residual biomass (including the guide wire) is usually chopped up straight away anyway, which allows for efficient logistics and good compaction within a silo. As subject of respective project work, biomass leftovers were ensiled in plastic barrels at high density ensuring it to be air tight. Plastic barrels were opened after 2, 4, 6 and 12 months duration in order to investigate the influence of the storage time on raw material properties and further processing. The dry matter content ranged from 26.90 to 25.16% during the ensilation and mass loss was observed below one percent. Structural carbohydrates and lignin are differing from various parts and proportion is not altered largely during ensilation shows the proper ensilation. Shives have higher cellulose content compared to the fibers and leaves having the least. Visual inspection showed no fungal attacks which relates to a good ensilation success. With the relatively acidic pH (5.5-6.5), acetic acid dominates the acid content whereas maximum of 2.37% of butyric acid is analyzed in the leave part of the 12-month ensiled biomass. Wet preservation of hop biomass leftovers shredded at the dimensions of 2-7 cm average length showed good results. As part of the project, the ensiled hop biomass is to be defibrated using a biomass extruder. Additionally, the intermediate can be further processed using a disc mill. Whilst the metal fragments from the guide wire do not appear to affect wet preservation, they do pose a challenge during this thermo-mechanical processing. However, commercially available detectors and magnets can be used here to ensure effective removal. The outlet aperture of the defibration extruder can be adjusted according to the size of the output fibers required. After wet processing the biomass moisture is decreased and the material is further dried in a tube or in a rack dryer. The processed output material accounts 13-17 percent of fresh material. Particle size distribution was studied for the biomass output and results showed a distinct influence of various storage durations. Within the project work, these processed fibers are sieved into various fractions and used for different purposes. The results produced so far by the project partners suggest that such hop fibers have potential as a filler with the plastic matrix of Polylactic acid via injection molding and extrusion.

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Energy use of manure in the Polish agricultural sector – analysis of resources and opportunities

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Abstract. Manure, the dominant natural fertilizer in Polish agriculture, represents a significant source of methane (CH4) and nitrous oxide (N2O) emissions within the agricultural sector. In the light of the increasingly stringent European Union climate policy, this carries serious environmental and economic implications. Poland produces approximately 83 million Mg of solid animal waste annually (primarily cow manure), with a relatively small proportion of liquid manure (slurry). Traditional storage of manure in heaps promotes anaerobic conditions that favor the emission of CH4 and N2O, gases with high global warming potential (GWP). The aim of this study was to quantify the energy potential of manure generated from livestock production in Poland, considering electricity and heat generation through cogeneration, as well as biomethane production as a substitute for natural gas. In this study, the energy potential of manure was estimated based on national production data and CH4 yield experiments conducted in a certified biogas laboratory. The total CH4 production potential was calculated at approximately 4.26 billion m3 per year, which corresponds to roughly 43% of the volume of natural gas imported by Poland from Russia in 2021. The achievable electrical capacity from cogeneration exceeds 2 GW. The utilization of manure in agricultural biogas plants can lead to a significant reduction in greenhouse gases (GHG) emissions, as well as the production of electricity with negative carbon intensity. The results indicate a substantial, currently untapped energy potential of manure and highlight the increasing importance of anaerobic digestion under evolving climate regulations and livestock production economics.

Keywords: farmyard manure, biogas plant, electric power, biomethane, digestates.

Acknowledgements. biogas plant, biomethane, farmyard manure, electric power, renewable energy.

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Life Cycle Assessment of Aspen-Derived Fuel-Grade Bioethanol via Nitrogen Explosive Decompression: Cooling-Water Representation and Energy-Driven Hotspots

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Abstract. Lignocellulosic bioethanol production requires careful environmental evaluation because its performance is strongly influenced by pretreatment configuration, thermal energy demand, downstream purification, and coproduct handling. This study presents a life cycle assessment of fuel-grade ethanol production from Aspen biomass pretreated using nitrogen explosive decompression (NED). The assessment was performed for a functional unit of 1 kg fuel-grade ethanol at the plant gate using the ReCiPe 2016 Midpoint (H) method. A central methodological focus was the representation of cooling water. In the process simulation, cooling water appeared as a large circulating utility flow. However, treating the full circulating flow as direct water consumption would overestimate water-related environmental burdens. Therefore, the cooling-water loop was set to zero in the LCA model to represent cooling water as a recirculating utility service rather than a net consumptive resource input. The results showed that the Aspen bioethanol system was primarily utility-driven. Climate change impact was approximately 78.85 kg CO_2-eq per kg ethanol, fossil resource scarcity was approximately 22.0 kg oil-eq, and water use was approximately 0.057 m^3 per kg ethanol. Contribution analysis indicated that condensation and heat integration, ethanol purification, and electricity-related utility processes were the dominant hotspots across the evaluated impact categories. These results show that the environmental profile was governed mainly by thermal energy demand, purification requirements, and electricity-related burdens rather than by direct cooling-water consumption. Overall, the study highlights the importance of consistent utility representation when integrating process simulation outputs with LCA. The findings demonstrate that high circulating cooling-water mass flows should not automatically be interpreted as high water-use impacts. Instead, energy integration, steam reduction, and purification efficiency are the most important improvement pathways for Aspen-based bioethanol production.

Keywords: Aspen biomass; bioethanol; nitrogen explosive decompression; life cycle assessment; cooling water; hotspot analysis.

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ANN modeling as a toll to determine the influence of biomass physical and chemical parameters on biomethane yield

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Abstract. Artificial neural networks (ANNs) have emerged as powerful tools for modeling complex, nonlinear relationships in anaerobic digestion systems, enabling accurate prediction of methane yield from diverse biomass substrates. This review synthesizes recent advances in ANN-based modeling applied to biogas production, with particular emphasis on identifying the influence of key physical and chemical parameters on methane yield. Critical substrate characteristics, including e.g. dry matter, organic dry matter (volatile solids), pH, hydraulic retention time, temperature regime, particle size, and pre-treatment methods are discussed in relation to their impact on digestion performance. Special attention is given to maize silage, which remains the dominant feedstock in European biogas plants due to its high biodegradability and stable supply. The variability of maize silage properties arising from harvest timing, ensiling quality, and particle size is examined, alongside the ongoing food-versus-fuel debate associated with energy crop utilization. Furthermore, sensitivity analysis techniques integrated with ANN models are evaluated as effective tools for ranking input variables and identifying dominant drivers of methane production under mesophilic and thermophilic conditions. Despite demonstrated high predictive accuracy, challenges related to limited datasets, model interpretability, and generalization remain. Overall, ANN-based modeling represents a promising pathway toward data-driven optimization of biogas production and improved sustainability of anaerobic digestion systems.

Keywords: anaerobic digestion, artificial neural networks, maize silage, methane production, renewable energy systems.

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Flowability and Fiber Breakage Behavior of Reed Canary Grass Along a Twin-Screw Extruder

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Abstract. The efficient mechanical processing of lignocellulosic biomass is a key challenge in biosystems engineering, particularly for the valorization of paludiculture crops such as Reed Canary Grass (Phalaris arundinacea). Twin-screw extrusion is increasingly used for biomass defibration and structural modification; however, the spatial evolution of bulk flow properties and fiber breakage along the screw axis remains insufficiently understood. This study investigates the axial development of flowability and structural transformation of Reed Canary Grass during twin-screw extrusion using ring shear characterization of material samples collected along the processing line. Material samples were extracted from seven defined axial positions (T1–T7) along a pilot-scale twin-screw extruder covering the feeding, compaction, defibration, and discharge zones. For each position, bulk mechanical properties were determined using a ring shear tester, including major principal consolidation stress (σ_1), unconfined yield strength (fc), flow function coefficient (FFC), bulk density (ρb), effective internal friction angle (φe), and static friction angle (φsf). Yield loci obtained from shear stress normal stress (τ–σ) measurements were used to characterize the shear resistance and flow behavior of the biomass under consolidation. Results show a clear spatial transformation of biomass structure and flowability along the extruder. In the feeding and early compaction zone (T1–T2), consolidation stress increases to approximately 20 kPa while unconfined yield strength ranges between 10 and 14 kPa, indicating strong fiber entanglement and cohesive material behavior. Corresponding FFC values around 1.5 classify the material as highly cohesive, suggesting limited flowability in this region. A pronounced transition occurs in the mid-process region between T2 and T5. The unconfined yield strength decreases by approximately 70%, while the flow function coefficient increases to values around 4.6. This shift reflects a transition from very cohesive to more flowable bulk behavior and indicates intensive fiber breakage and reduction of mechanical interlocking between particles. At the same time, bulk density increases from approximately 98 $kg \cdot m^{-3}$ to 167 $kg \cdot m^{-3}$, demonstrating progressive consolidation combined with structural fragmentation of the biomass. In the final processing zone (T6–T7), bulk density reaches its maximum value of approximately 187 $kg \cdot m^{-3}$. A moderate increase in cohesive strength is observed, suggesting re-compaction and pressure build-up before discharge through the extruder outlet. The axial evolution of shear strength and flowability presented in this study provides experimental insight into the internal mechanical transformation of biomass during twin-screw extrusion. The results contribute to a better understanding of fiber defibration mechanisms in continuous biomass processing systems and provide a basis for improving screw configuration design and developing predictive rheological models for biomass conversion processes.

Keywords: Twin-screw extrusion, Biomass rheology, Shear strength, Fiber fragmentation Flow function coefficient (FFC).

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Investigation and Production of Renewable Solid Biofuels via Torrefaction of Pellets from Agricultural Waste

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Abstract. Agricultural residues represent an abundant and renewable feedstock for producing sustainable solid biofuels, yet their direct utilization is limited by low energy density, high hygroscopicity, and insufficient mechanical strength. This study investigates how slow pyrolysis (torrefaction) at controlled temperatures influences the structural, mechanical, and energetic properties of pellets produced from wheat straw, barley straw, and oat husks, with peat and barley bran used as natural binders. The work aims to identify optimal combinations of feedstock, binder type, and torrefaction severity that enhance fuel quality while maintaining sufficient product yield for practical application. Biomass mixtures were pelletized and torrefied at 220, 270, and 320 °C under an inert nitrogen atmosphere. A comprehensive characterization was performed, including analysis of bulk density, compressive strength, mechanical durability, hygroscopicity, elemental composition, and calorific value. The raw biomass demonstrated substantial compositional variability: wheat straw exhibited the highest lignin content, barley straw contained the most cellulose, and oat husks showed the highest hemicellulose fraction. Initial pellet tests revealed that bran-based pellets achieved higher cohesion and fewer microcracks compared with peat-based formulations, especially at higher biomass content. Torrefaction at 220 °C preserved high product yields (>90%) across all formulations, with minimal deterioration of mechanical strength. Bulk density and compressive strength decreased progressively with increasing temperature, reflecting devolatilization and degradation of natural binding structures. Above 270 °C, pellets exhibited pronounced declines in strength, especially those containing peat or derived from oat husks. Nevertheless, most pellets, except oat-husk-based formulations, consistently met the ISO 17225-2:2021 mechanical durability requirement (≥96%), confirming their suitability for industrial handling and long-distance transport. The energetic properties improved markedly with increasing torrefaction severity. Gross calorific value increased from approximately 18–20 MJ·kg^{-1} in raw pellets to 21–25.8 MJ·kg^{-1} at 320 °C, accompanied by carbon enrichment to 45–47%. Strong positive correlations were observed between calorific value and elemental carbon content, as well as between relative energy gain and mass loss. These trends confirm that thermochemical upgrading during torrefaction is closely linked to the progressive removal of oxygenated volatiles. However, higher temperatures also caused substantial solid mass reduction (35–44%), highlighting a trade-off between fuel quality and product yield. Hygroscopicity improved significantly at elevated torrefaction temperatures, decreasing to 7–10% at 270–320 °C and enhancing the hydrophobicity and storage stability of the pellets. Bran proved to be a more thermally stable binder than peat, maintaining superior pellet cohesion and energy performance across the full temperature range. Overall, the results demonstrate that torrefied pellets derived from agricultural residues can serve as high-quality, transport-stable, carbon-rich solid biofuels with performance comparable to fossil fuels. Moderate torrefaction (≈220 °C) offers an advantageous balance between mechanical stability and yield, whereas higher temperatures maximize energy density and carbon content. The findings provide a practical framework for optimizing torrefaction parameters and feedstock–binder combinations to support the wider deployment of renewable solid biofuels within the bioenergy and biorefining sector.

Keywords: Torrefaction; Agricultural waste; Biochar; Calorific value; Sustainable biofuels.

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Analysis of the Chemical Composition of Biogas Depending on the Organic Substrate Used and Its Impact on Energy Production

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Abstract. Large volumes of agricultural residues and food waste, often discarded as by-products of farming and consumption, can be effectively valorized through anaerobic digestion to produce biogas, transforming organic waste into a renewable source of energy. The aim of this paper was to investigate the chemical composition of biogas and the energy produced depending on the substrate used. The impact of agricultural waste (A), livestock waste (B) and mixt food waste (C) on biogas composition and energy production was assessed using and I-optimal mixture design, then the optimal combination was established using the Design Expert software (trial version). The data was collected from a biogas Plant in Vornicenii Mici, Suceava, Romania. The dependent variables were methane concentration, oxygen concentration, hydrogen sulfide concentration, and energy production in a day (1 engine, 8h of functioning). The results revealed that the special cubic mathematical model fitted well the experimental data for all the dependent variables ($0.90 < R2 > 0.97$, $p < 0.05$). Methane concentration was significantly affected ($p < 0.05$) by the AB, AC, and ABC interaction of components. Oxygen concentration of the biogas was significantly influenced ($p < 0.05$) only by AB and ABC interaction, while AC and ABC interaction had a significant effect ($p < 0.05$) on hydrogen sulfide level. Energy production was affected by all the interactions between components ($p < 0.05$). Hydrogen sulfide negatively impacts biogas quality by causing corrosion of engines, turbines, pipelines, and storage systems, reducing equipment lifespan and increasing maintenance costs, while also lowering energy conversion efficiency and posing health and environmental risks if not adequately removed before energy production. In addition, oxygen in biogas adversely affects energy production by diluting the combustible methane fraction, increasing the risk of corrosion and explosion, inhibiting anaerobic microbial activity, and reducing the overall efficiency, safety, and stability of biogas utilization systems. On the other hand, higher methane content leads to greater power output, more stable combustion, and improved overall performance of the plant. Thus, for the optimization of components (A, B, and C) the methane level and energy production were maximized, oxygen level was kept in range, and the hydrogen sulfide level was minimized. The optimal combination of biomass was established at 81.22% agricultural waste, 16.79% livestock waste and 1.99% mixt food waste. In these conditions, the biogas contains 64.46% methane, 0.92% oxygen, 2.46% hydrogen sulfide, and the energy production would be 15.69 MWh/day. In conclusion, the practical application of this paper lies in guiding the selection and optimization of organic substrates for anaerobic digestion by demonstrating how different waste streams influence biogas composition and resulting energy production, thereby supporting more efficient, reliable, and sustainable biogas system design and operation.

Keywords: biogas, co-generation, green energy, waste valorization, optimization.

VII ENERGY USAGE AND STORAGE

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Rapid Pre Screening Methodology for Small Capacity Lithium Ion Cells for Subsequent Reuse Experiments

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Abstract. The increasing availability of used lithium ion cells has created a demand for simple and reliable methods to assess their suitability for reuse. This study presents a low complexity, decision oriented methodology for the initial pre screening and grouping of small capacity lithium ion cells for subsequent reuse applications. The proposed approach is based on short duration direct current resistive load tests employing a 3 30 3 protocol. The cells are connected in series, enabling direct comparison of voltage drop and internal resistance (DCIR) characteristics. Under controlled conditions, lithium ion cells with a nominal capacity of approximately 500 mAh, recovered from e cigarette batteries, were tested. A dedicated test rig was developed to allow rapid cell replacement and partial automation of the testing process. The primary evaluation criterion was the voltage response during 30 second load pulses at approximately 0.6 C, followed by a short term stress pulse at approximately 1.2 C to identify borderline cells. Cells that successfully passed the screening were assembled into a 3S3P (three cells in series, three in parallel) battery pack based on similar voltage behavior. To assess group compatibility, a conservative charging procedure was applied to the assembled pack (12.6 V, 300 mA, corresponding to 0.2 C). A low power (10 W) power supply and a CC/CV charging method were used, allowing observation of voltage equalization between parallel groups without inducing significant thermal stress. During low current charging, voltage differences between parallel groups decreased, indicating acceptable electrochemical consistency. One assembled battery pack was integrated as a standalone power supply for a FläktWoods 227VM pressure regulator, successfully demonstrating practical reuse in biomass drying experiments. The results indicate that short term voltage response under load is a sufficient indicator for the initial selection and grouping of cells. However, a thermal incident observed during the test series highlights that the proposed method does not replace comprehensive diagnostics or continuous safety monitoring.

Keywords: DC pulse testing; 3 30 3 protocol; diagnostic algorithm; small capacity cells; e cigarette waste; internal resistance; pre screening; circular economy.

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VIII ERGONOMICS AND ERGODESIGN

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Internal security leadership, resilience, and immersive simulation for transforming training practice: Theoretical aspects

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Abstract. Internal security organisations across the Baltic Sea region operate in complex socio-technical environments defined by hybrid threats, societal fragmentation, and cascading crises. These conditions place sustained cognitive, emotional, and organisational demands on personnel, challenging traditional training systems that remain focused on procedural and technical competencies. Emerging research underscores that leadership styles, organisational culture, and ergonomically designed work environments significantly influence resilience, health, and performance under stress. In parallel, European and national policy frameworks increasingly prioritise digital transformation and the adoption of innovative learning technologies within internal security education. The research question guiding this review is: How can human-centred leadership, ergonomics, and organisational culture be integrated through immersive simulations to enhance systemic resilience in internal security training? This study conducts a systematic literature review, synthesising interdisciplinary evidence related to human-centred leadership, ergonomics, organisational culture, and immersive simulation. Sources from major academic databases and policy archives published between 2015 and 2025 were analysed through a socio-technical and biosystems engineering lens to identify convergent patterns shaping resilience and training effectiveness. Findings highlight that resilience among internal security personnel emerges as a dynamic, system-level outcome rather than an individual trait. Human-centred leadership and well-designed ergonomic systems foster stronger organisational resilience, while immersive virtual and mixed-reality simulations enhance embodied learning, teamwork, and decision-making under stress. The study concludes that integrating leadership, ergonomics, and simulation within a unified, human-centred training model aligns with both Baltic regional security needs and the European agenda for digital transformation, offering a robust foundation for evidence-based reform in internal security education.

Keywords: ergonomics, internal security, leadership, resilience, simulation.

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Predicting Work–Rest schedule for Firefighting activities based on core temperatures using of PHS Model

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Abstract. The Predicted Heat Strain (PHS) model (ISO 7933) is used to estimate physiological strain and acceptable exposure times under heat stress, yet its accuracy in extreme occupational conditions remains uncertain. This study aimed to compare PHS model predictions of work–rest cycles with actual physiological responses measured during a simulated structural firefighting scenario. Eight (n = 8) volunteer firefighters participated in two experimental sessions in spring 2024 using two different dressing strategies: departing from the fire station already in full turnout gear or donning turnout gear only at the incident site when the need for smoke diving is obvious. Test persons completed a standardized protocol consisting of pre-work, heat exposure during treadmill exercise in a hot environment, and post-exposure recovery under neutral conditions. Core and skin temperatures were continuously monitored, and safety thresholds were applied. All test persons completed the full exposure without exceeding termination criteria. PHS model predictions showed discrepancies with measured responses: the PHSLU version overestimated, while the PHSFL version underestimated actual physiological strain and recovery times. These differences indicate potential risks, as underestimation may increase health hazards, whereas overestimation may unnecessarily limit task performance, and highlight the need for model refinement based on experimental data from human subjects to improve occupational heat stress assessment.

Keywords: firefighter, heat stress, predicted heat strain model, protective clothing, thermal insulation.

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Socio-Technical Resilience in the NIS2 Era: A Framework for NIS2-Regulated Entities in Operational Energy Systems

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Abstract. Directive (EU) 2022/2555 (NIS2) increases cybersecurity risk-management and incident-reporting expectations for organisations operating essential energy services. In operational energy systems, these obligations intersect with cyber-physical control, safety constraints, shift-based work, and vendor access, where non-compliance often emerges as a rational local adaptation to production pressure rather than negligence. This theoretical study synthesises recent operational-technology security and human-factors cybersecurity literature and maps selected NIS2 risk-management measures to interventions that are compatible with operations. Using Protection Motivation Theory (PMT), the study treats response cost as a design constraint that shapes routine behaviour and operationalises work-system fit through a Human-Centric Compliance Matrix (HCCM) that links a control objective, a plausible failure mode, and evidence suitable for management oversight and audit expectations. The resulting framework (STRNIS2) maps selected NIS2 measures to concrete controls such as vendor access control, backup verification, and recovery drills that can be used in availability- and safety-critical operations. The article argues that cybersecurity measures are more likely to hold when they are built into routine work rather than added as separate administrative tasks.

Keywords: cyber-physical systems, energy sector, Ergonomics, human factors, NIS2, operational technology, resilience, SMEs, socio-technical systems.

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Design of a modular methodological framework for the assessment of work-related musculoskeletal pain

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Abstract. Work-related musculoskeletal pain can be an early indicator of a developing health condition. When pain is not recognized and managed properly, it might intensify, become chronic, and negatively affect the functional abilities of the worker. This can create challenges for both employers and employees and may result in health and economic loss. Challenges related to the prevention and prevalence of occupational musculoskeletal pain might appear at the worker, management or organization level. Potential issues include resistance to change, non-compliance with safety protocols, lack of commitment and support, prioritizing productivity over the health of the workers, and limited organizational resources such as time, funding, and staff. To address this, a modular methodological framework is proposed for mapping the prevalence, potential causes and risk factors of occupational musculoskeletal pain. This framework is constructed from three assessment modules and one recommendation module. The first module is the prevalence module, and its intention is to collect data related to occupational musculoskeletal pain. The second module focuses on causality issues, and the third module evaluates relevant risk factors. The purpose of this framework is to reduce the workload associated with the risk assessment of a workplace, particularly in industries where individual assessment is challenging, costly, and time-consuming, and to support the identification of broader patterns of work-related musculoskeletal pain with the potential use in prevention and intervention related to work-related musculoskeletal disorders.

Keywords: work-related musculoskeletal pain, work-related musculoskeletal disorders, prevention, modular framework, risk assessment.

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Potentially Fatal Incidents: Identification, Classification and Human Factor Analysis

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Abstract. Potentially Fatal Incidents (PFIs) are increasingly used as leading indicators in high-risk industries, yet their definitions, classification criteria, and investigative depth vary widely across organisations, limiting their preventive value and comparability. Human factors (HF) play a critical role in determining whether incidents escalate into PFIs and must be considered together with technical and organisational barrier performance. This research aims to examine the role of human and organisational factors in PFI identification, analyse misclassification patterns, and propose a human-factors-based model to improve PFI classification consistency and learning value. A retrospective document analysis was conducted using incident reports from a heavy-industry organisation covering the period from 2020 to 2024. The dataset was systematically reviewed and PFI classifications were re-evaluated using a structured framework integrating hazardous energy and exposure assessment, barrier performance evaluation based on Bow-Tie logic, and human and organisational factor coding using an HFACS-based structure. Analysis revealed inconsistency in PFI classification, including overclassification and under-classification linked to limited recognition of human and organisational factors. Number of incidents were labelled as PFIs despite lacking credible fatal energy exposure, while other events with systemic and human-factor contributors associated with fatal risk were not recognised as PFIs. The HF-PFI Model demonstrated improved classification reliability by integrating energy exposure, barrier status, human factor categories, and systemic indicators. Integrating human-factors analysis into PFI identification can strengthen serious injury and fatality prevention in high-risk industrial environments.

Keywords: Potentially Fatal Incidents, human factors, accident investigation, safety culture, heavy industry, systemic safety, risk assessment.

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Changes in Blood Pressure, Heart Rate, and Grip Strength in Latvian Bank Office Employees: A Pilot Study

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Abstract. Background: Office work in the financial sector combines prolonged sedentary behaviour, repetitive computer-based hand activity, and sustained cognitive demands. These exposures may produce measurable within-day physiological changes that can serve as early signals of workload-related strain. Objective: To quantify within-day (pre–post) changes in blood pressure, heart rate, and hand/finger grip strength among Latvian bank office employees and to explore inter-individual patterns relevant for ergonomics. Methods: A pilot observational study was conducted in one of the largest commercial banks in Latvia. Fourteen office employees participated. Physiological measurements were collected at the start and end of the workday across several workdays, including systolic and diastolic blood pressure, heart rate, and hand and finger grip strength. Descriptive statistics were used to characterise within-day changes and variability between participants. The study followed ethical requirements and received approval from the University of Latvia Ethics Committee (Protocol No. 13-28/60, 15 April 2025). Results: Within-day responses demonstrated substantial inter-individual variability in cardiovascular measures, indicating heterogeneous physiological reactions to daily office work demands. Women showed higher heart rate values than men across measurements, while blood pressure changes were generally moderate but variable. Hand grip strength showed an average increase of approximately 14–18 kg from morning to end of day, whereas a subset of participants exhibited decreases, suggesting possible fatigue-related or task-related differences in neuromuscular response. Finger grip strength decreased by ~1–3 kg on average by the end of the workday, consistent with functional fatigue in fine motor musculature associated with prolonged keyboard and mouse use. Age-related tendencies were observed: younger employees more often displayed larger within-day shifts across indicators, while older employees showed more stable patterns. Conclusions: In this Latvian bank pilot sample, pre–post workday measurements of blood pressure, heart rate, and grip strength captured measurable within-day physiological dynamics with marked heterogeneity across individuals. The combination of cardiovascular and grip-strength indicators appears promising for identifying early workload-related strain patterns in office work and for informing targeted ergonomic and work-organisation measures in larger studies.

Keywords: office employees; banking sector; within-day change; blood pressure; heart rate; grip strength.

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IX FOOD SCIENCE AND TECHNOLOGY

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Fermentation-Based Valorization of Whey for Bioactive Peptides Production and Analysis

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Abstract. Whey, a major by-product of cheese manufacturing, represents both a rich nutrient source and a significant environmental pollutant if not properly managed. In Latvia dairy industry generates ca. 400,000 tons of whey annually, and just about 50% of that volume is processed to higher value-added products, while the rest is discarded, creating ecological challenges and economic losses. Current valorization technologies are not tailored for the needs of regional industries, dominated by small and medium-sized enterprises (SMEs) with limited capex capacity. The aim of our research is to develop an optimized microbial fermentation process for industrial-scale conversion of whey protein into bioactive peptide preparations. We have screened more than 20 lactic acid bacteria (LAB) and lactose fermenting yeast (LFY) strains for peptide accumulation propensity. The strains were obtained from natural isolates maintained in the Microbial Strain Collection of the University of Latvia (MSC UL, International Depository Authority, ERIC MIRRI member). Optimized, whey-based cultivation medium and fermentation parameters have been developed; natural strain isolates were compared to the industrial strains used in cheese processing. Following initial tests on skim-milk agar, peptide accumulation was characterized, and peptides were profiled using ninhydrin, SDS-PAGE, and ultrafiltration analysis. Bioactivity assays addressing antimicrobial and antioxidant properties were performed having in a view to eventual development of additives for food and hygiene products. The results of LAB and LFY strain screening, paying special attention to the correlation of the results of biochemical and bioactivity tests, are provided. Further pilot-scale culture expansion in 5-10 L bioreactors will assess the scalability, while collaboration with the Latvian dairy producers will evaluate the prospects of increasing the technology readiness level.

Keywords: whey valorization, bioactive peptides, lactic acid bacteria, fermentation.

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Ultrasound-Assisted Green Extraction of Anthocyanins from Black Elderberry By-products Using Ethanol and Natural Deep Eutectic Solvents

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Abstract. During the production of berry juice, approximately 10% to 35% of the berry mass remains as by-products, primarily consisting of berry peels and seeds. The seeds found in the berry pulp are rich in oils, while peels contain high levels of dietary fibre and polyphenols, including anthocyanins, phenolic acids, and flavonols, often at higher concentrations than in the juice itself. Black elderberries (Sambucus nigra L.) are particularly rich in anthocyanins, which give them their characteristic dark blue or even black colour, which makes the by-products of black elderberry juice production particularly suitable for anthocyanin extraction. Once extracted and further processed in the food industry, anthocyanins can be used as natural colourants or as biologically active ingredients in dietary supplements. Additionally, products containing ingredients derived from natural sources are increasingly appealing to consumers. This study aimed to assess the effectiveness of natural deep eutectic solvents for ultrasound-assisted extraction of anthocyanins from black elderberry by-products and to compare their effectiveness with that of conventional ethanol-water media. In this study, three different solvents were used for anthocyanin extraction: a 45% ethanol-water (E) solution; a citric acid-xylitol (CAX) solution with a molar ratio of 2:1 and 20% water; and a betaine-citric acid (BCA) solution with a molar ratio of 2:1 and 30% water. Lyophilised elderberry pulp was extracted using an ultrasonic device, the Sonopuls HD4200 (Bandelin Electronics GmbH & Co., Germany), equipped with a TS 104 sonotrode with a diameter of 4.5 mm. The ultrasonication process was carried out for 10, 15, and 20 minutes with each solvent in a ice cold water bath. By the end of the process, the samples' temperature did not exceed 33 ± 2 °C, and sonication was performed at 21% amplitude. As control samples, each solvent was stirred using a magnetic stirrer for 20 min. Total anthocyanin content was determined spectrophotometrically using the pH differential method. Results showed that the highest anthocyanin extraction yield was obtained with an E solution after 10 minutes of ultrasonication, with a value of 1433.84 mg 100 g-1. For the CAX solution, the highest anthocyanin extraction yield was achieved after 15 minutes of ultrasonication – 1316.38 mg 100 g-1, while for the BCA solution, it was achieved after 10 minutes of ultrasonication, yielding 1206.35 mg 100 g-1. All samples in the control treatment, which were stirred with a magnetic stirrer, had significantly ($p<0.05$) lower anthocyanin content than those subjected to 10 or 15 minutes of ultrasonication. Additionally, a significant ($p<0.05$) decrease in anthocyanin content was observed across all samples after 20 minutes of ultrasonic treatment. The results of the study confirm that ultrasonication is an effective method for enhancing the release of anthocyanins from black elderberry processing products. Additionally, the use of both ethanol and natural deep eutectic solvents offers considerable potential for extraction. Black elderberry by-products are valuable raw materials for anthocyanin extraction and are well-suited for creating a waste-free processing cycle.

Keywords: Pigment extraction, berry pulp volarization, sonication, sustainable processing.

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Global Vitamin D Deficiency and the Future of Sustainable Microalgal Vitamin D Production

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Abstract. Vitamin D deficiency is a growing global public health challenge. This deficiency is linked to impaired bone health, immune dysfunction, metabolic disorders, and increased chronic disease risk. Simultaneously, rising demand for vitamin D is placing pressure on current production systems, which rely predominantly on animal-derived lanolin and energy-intensive chemical synthesis, raising concerns over sustainability, ethical acceptability, and long-term supply resilience. As nutritional supply chains become increasingly shaped by resource efficiency and decarbonization, vitamin D production is emerging at the intersection of the energy–nutrition nexus. Current production trends expose important sustainability gaps, prompting interest in bio-based alternatives. Among these, microalgae represent a promising long-term platform for vitamin D production due to their high productivity, limited land and freshwater requirements, and potential for carbon capture. While not yet positioned as an immediate replacement technology, microalgal vitamin D offers a strategic future pathway to support nutritional security while aligning with sustainable bioeconomy objectives and energy-transition frameworks, including the United Nations Sustainable Development Goals and the European Green Deal.

Keywords: Vitamin D deficiency; Sustainable nutrition; Microalgae; Circular bioeconomy; Carbon footprint; Sustainable Development Goals; European Green Deal.

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Optimisation of Drying Techniques to Preserve Bioactive Compounds in Spruce Sprouts During Storage

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Abstract. Spruce sprouts are a rich source of vitamins and antioxidants. Still, there is little information about the stability of compounds in different dried spruce sprouts during storage. This study aims to analyse the optimal drying method for spruce sprouts to ensure higher bioactive compound content for a shelf life of one year. Four types of spruce sprouts were analysed – fresh, dried at 40˚C, at 60˚C, and freeze-dried. Spruce sprouts were analysed for moisture, Vitamin C content, total tannin content, α-, and β- chlorophyll, total chlorophyll and total carotenoids, as well as volatile compounds in different spruce sprouts were characterised. To evaluate the optimal drying method for preserving bioactive compounds for over a year, the multi-criteria method TOPSIS was used. According to the multi-criteria method TOPSIS, the most optimal results were observed in fresh samples. However, when analysing drying methods, the most optimal for spruce sprouts were freeze-drying and drying at 40˚C. Characterising volatile compounds in different processed spruce sprouts, regardless of the drying method, D-Limonene had the highest concentration in all samples, which gives the spruce sprouts a citrus aroma. Overall, the results indicate that while fresh spruce sprouts initially contained higher content of bioactive compounds, freeze-drying proved to be the most effective method for preserving these compounds during storage for a year. This method not only ensures long-term stability but also offers a promising approach for developing stable, nutrient-rich spruce sprout products with extended shelf life and high functional value suitable for industrial applications

Keywords: chlorophyll, freeze drying, TOPSIS, Vitamin C, volatile compounds.

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Scented candles in vegetable crop protection: first steps in progress

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Abstract. In the light of decreasing availability of synthetic pesticides, increasing pressure by emergence of resistance as well as health and environmental risks, alternative crop protection technologies are a vast alley to be studied. Botanical sprays have been found to be safer and natural, but they may raise several issues like short persistence, inconsistent effect, narrow spectrum, potential phytotoxicity, high cost, lack of supply etc. For a plant grower, it would be virtually impossible to re-apply the spray after every rain shower, needed to secure the full benefit of attractant, antifeedant or repellent effect of natural preparations. Therefore, we search more stable carrier material for botanical scents known to modify the insect olfactory response and behavior. Commercially available aromatic candles were tested since 2022 to check the effect in agricultural applications. Field trials were conducted in replicated cabbage plots, where unlit scented candles were placed at regular intervals between plants and compared with unscented plots and a separate control area. Pest pressure and natural enemy activity were assessed using yellow sticky traps and direct plant inspections during the main flight period. In contrast to experimental plots of cabbage equipped with lavender and cinnamon candles and neighboring empty plots, the control area further away was infested by Pieris brassicae second generation larvae first. In scented plots there was higher presence of anthophilic insects like Thysanoptera, Diptera and Hymenoptera caught by yellow sticky traps. The abundance of mummified aphids and the activity of parasitoid wasps were higher in the vicinity of lavender candles, even though there was no significant difference in the amount of aphid Brevicoryne brassicae. The effect of attractant remained lower in plots closest to the field edge, within the natural flight range of parasitoids. In the quest for more natural solutions, advantages of various carrier materials were tested in potato crop in 2023. Five types of lavender candles were handmade of which most stable was parafin, however no significant setbacks appeared also in soy wax, bees wax nor in rapeseed wax candles. Least easy was the field application of sheep tallow candles due to their low melting point causing them to liquify in hot summer days and they were also bird-pecked. Colorado Potato Beetle didn't expose any behaviour change near lavender scent source. Unlike companion plants, scent candles don't compete with the main crop, therefore act without compromising the yield. As our experiments confirmed, unlit lavender candles placed between cabbage plants as a repellent for the Large White and scent attractant for parasitoids can successfully complement an existing integrated pest management system. Our results confirm that the strongest effects occur under warm, calm conditions, when wax softening increases the release rate of volatile compounds within the crop canopy; in cooler or rainy periods, volatility and scent persistence are reduced as was shown by less pronounced effect in a rainy season of 2025. Future work will optimize wax composition and dispenser placement and will quantify outcomes (larval densities, parasitism rates, and yield) to define where scented candles add the most value within IPM.

Keywords: attractant, olfactory response, lavender aroma, crop protection innovation, integrated pest management.

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Microbial Heritage in Traditional Rye Sourdough: Functional and Safety Insights into Lactiplantibacillus plantarum Strains

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Abstract. Lactiplantibacillus plantarum is a widely distributed lactic acid bacterium inhabiting diverse food ecosystems, including traditional sourdough fermentations. Its prominence reflects an extensive metabolic repertoire, strong ecological adaptability, and production of bioactive metabolites with antimicrobial functions. However, the increasing use of commercial starter cultures has reduced the prevalence of locally adapted strains that may harbour unique functional and safety-related traits. Characterizing indigenous L. plantarum populations from heritage sourdoughs is therefore essential for preserving microbial diversity and supporting the technological resilience and authenticity of traditional fermentations. This study evaluated L. plantarum strains from traditional Estonian rye sourdoughs for safety, enzymatic and fermentative traits, exopolysaccharide (EPS) production, and mycotoxin-binding capacity. All L. plantarum strains were non-hemolytic and susceptible to clinically relevant antibiotics. The isolates displayed considerable enzymatic and metabolic variability, with high aminopeptidase and β-glucosidase activities reflecting strong proteolytic and glycolytic potential. Carbohydrate utilization patterns showed broad substrate adaptability and notable differences between and within genotypes. During rye sourdough fermentation, all strains rapidly acidified the dough to pH < 4.5 and produced lactic and acetic acids in ratios around 87:13, within the optimal range for sourdough quality, demonstrating strain-dependent fermentation kinetics. EPS production ranged from 131.4–225.2 mg/L, with stable yields and sugar compositions across genotypes. Exposure to aflatoxin B_1 did not affect fermentation performance, and all strains exhibited high toxin-binding efficiency (~100%), indicating potential for biological detoxification of contaminated cereals. Overall, the studied L. plantarum strains demonstrated functional robustness, combining efficient fermentation, stress resilience, and mycotoxin-binding capacity. These traits confirm their safety, metabolic versatility, and technological reliability, supporting their suitability as multifunctional starter cultures for sustainable, high-quality, and nutritionally enhanced fermented foods.

Keywords: fermentation, enzymatic activity, antibiotics, aflatoxin B1, exopolysaccharides.

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Antioxidant and antibacterial activity of tea and mate extracts

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Abstract. Consumers are increasingly interested in natural, plant-based additives as alternatives to synthetic compounds in food products. This study investigated the polyphenolic profiles, total polyphenol content (TPC), total antioxidant capacity (TAC), and antibacterial activity of aqueous and 30% ethanolic extracts of green tea, matcha tea, black tea, and yerba mate. Commercial teas (Camellia sinensis) and mate (Ilex paraguariensis) were purchased in Tartu, Estonia. The tea and mate leaves were powdered (< 1 mm), and extracts prepared with water or 30% ethanol. Polyphenolic compounds were analysed using HPLC-DAD-MS, TPC was quantified as gallic acid equivalents, and TAC was determined spectrophotometrically using the Folin-Ciocalteu method. Minimum inhibitory concentrations (MICs) against Listeria monocytogenes, Staphylococcus aureus, Escherichia coli, and Campylobacter jejuni were determined by broth microdilution according to the EVS-EN ISO, 20776–1:2020 standard. In total, 28 polyphenolic compounds were detected, including hydroxybenzoic acids, hydroxycinnamic acids, flavanols, flavonols, and tea pigments. Mate extracts were rich in chlorogenic acids, while tea extracts contained higher proportions of flavanols, particularly epigallocatechin, epicatechin gallate, and epigallocatechin gallate. Ethanolic extracts of mate (5.16 ± 0.02 mg GAE/mL) and green tea (4.68 ± 0.08 mg GAE/mL) had the highest TPC, wheras matcha tea (5.50 ± 0.01 mg GAE/mL) and green tea (5.82 ± 0.00 mg GAE/mL) showed the strongest TAC. In aqueous extracts, mate and green tea had the highest TPC (3.02 ± 0.34 and 1.77 ± 0.03 mg GAE/mL, respectively), and the strongest TAC (4.05 ± 0.01 and 3.48 ± 0.10 mg GAE/mL). All extracts inhibited the growth of S. aureus, with MIC values ranging from 0.06 to 0.27 mg GAE/mL, and green tea extracts showed the strongest antibacterial activity. Mate extracts showed similar TAC and antibacterial activity in both aqueous and ethanolic extracts. TAC correlated most strongly with TPC (rS = 0.8), and among individual compounds, epicatechin gallate showed the strongest correlation (rS = 0.6). A moderate negative correlation (rS = − 0.6) between TPC and MICs indicated that higher polyphenolic content was linked to stronger antibacterial activity. In summary, ethanolic extracts of green tea were the most promising for further application in food composition due to their strong antioxidant and antibacterial properties. These findings highlight the potential of tea and mate extracts as natural alternatives to synthetic additives in the food industry.

Keywords: polyphenols, antioxidant, antibacterial, tea, mate.

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Do phospholipolysis and bacteria primarily regulate linoleic acid oxidation in fresh meats?

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Abstract. The release of polyunsaturated fatty acids (PUFA) from cell membranes by phospholipolysis followed by (per)oxidation, is the major integrated process in the oxidative spoilage of meat. Only free PUFAs are susceptible to oxidation. Rancid meat is an excellent medium for the growth of various microbes, which in turn contribute to the release and oxidation of new PUFA molecules. Due to dominance of linoleic acid (LA) among PUFAs, its oxidation of is the most important in meats. This study is the first attempt to quantitatively describe the oxidation of LA from start to finish, specifically to the toxic secondary oxidation product malondialdehyde (MDA). Oxidation begins after the release of LA from cell membrane phosphatidylcholines (PL), during which lysophosphatidylcholines (LPC) are formed under the catalysis of lipolytic phospholipases A (PLA 1 and 2) (EC 3.1.14). Process continues with combined sequential enzymatic and free-radical formation primary oxidation products called oxylipins (OL), and ends with the formation of secondary oxidation products, mostly various aldehydes, including MDA, which is toxic and mutagenic especially for bacteria. The two main enzymatic routes involved in LA oxidation are lipoxygenase (LOX) and cytochrome P450 oxidase (CYP450) pathways. Experimental. The lipolytic and oxidative processes in minced porcine, bovine, rainbow trout, and chicken meats were modified by six natural additives (powders of apple, black currant, aronia, tomato, garlic, and garden rhubarb (all 2% w/w)). During the 14-day storage at refrigerator temperature, the concentrations of LPCs 1 and 2 and MDA were determined periodically by LC-Q-ToF-MS and HPLC-DAD, respectively. Total counts of aerobic microorganisms and Pseudomonas spp. were estimated using ISO methods. Results. There is no clear correlation between concentration of MDA (or OLs) and LPC, but a zigzag temporal pattern exists that generally reflects the two main (lag- and log-) phases of the growth of aerobic microorganisms and Pseudomonas spp. During the first 1–4(6) days, the content of LPCs and MDA is positively correlated due to the autooxidation of LA. Mostly between days 6–8, the LPC content drops, whereas the production of OLs and MDA continues. The reserve of LPCs from autooxidation is obviously depleted around the 8th day. However, here the log phase of microbial growth starts, providing a fresh supply of LA and other PUFAs. The rapid increase in the content of LPCs and MDA after the 8th day is especially distinct in meat with tomato powder. Plant additives modulate the process by either accelerating or slowing down different phases. The described pattern is best visible in porcine meat, less so in beef and not at all in trout and chicken meats due to the low level of free LA throughout the whole oxidation process. Conclusion: In order to purposefully extend the shelf life of minced meats, in addition to the antibacterial and antioxidant (mostly radical scavenging) effects, the antilipolytic effects of additives should also be taken into account. The research in this topic is ongoing.

Keywords: lipolysis, phospholipase A, lysophosphatidylcholines, bacteria, PUFA oxidation.

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10-hydroxystearic acid as a potential quantifiable marker of bacterial contamination in meats

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Abstract. 10-hydroxystearic acid (10-HSA) is the major oxygenated derivative of oleic (cis-9-octadecenoic) acid, a monounsaturated n-9 fatty acid (MUFA). The corresponding metabolic reaction, which can be classified as both oxidation and hydration (addition of a water molecule to an isolated double bond), is mainly catalyzed by oleate hydratase (OhyA), a member of flavoenzyme family, These enzymes, classified as hydro-lyases (EC 4.2.1.53) are of interest for industrial applications due to their role in the generation of hydroxy fatty acids, which are used in surfactants, lubricants, and biodegradable polymers. 10-HSA, which can be further oxidized to 10-ketostearic (10-KSA) and 9,10-epoxystearic (9,10-ESA) acids, is produced only by bacteria, such as ruminant species (Selenomonas ruminantum, Enterococcus faecalis, etc) or multiple other bacteria (Staphylococcus, Bacillus, Listeria,, Pseudomonas) that live in various contaminated fresh meats (Radka et al, 2021). Porcine and trout meat do not naturally contain 10-HSA, but beef may contain 10-HSA, which is deposited from the rumen to meat and milk. The corresponding OhyA is not found in ruminant meat. The gene encoding OhyA is found in different bacteria and is involved in processes such as surviving stress, modulating membrane composition, etc. However, Pseudomonas aeruginosa that lacks OhyA, is using other enzyme systems, for example lipoxygenase (LoxA) (Morello et al, 2019). There are multiple chemical and biochemical markers of bacterial levels and activities in meat – pH, enzyme activities (such as of catalase or coagulase), metabolic end products (such as hydrogen sulfide, indole, ammonia, volatile organic compounds (VOC) like histamine). Total volatile basic nitrogen (TVB-N) is another quantifiable indicator of bacterial spoilage. The knowledge that 10-HSA is synthesized only by bacteria inspired us to investigate the utility of this oxylipin as a potential biochemical marker for assessing the level of bacterial contamination in meats. We investigated the formation of 10-HSA in minced porcine, bovine, and rainbow trout meat for 8 or 11 days at refrigerator temperatures by LC-MS/ToF and correlated the results with the CFU/g values obtained by enumeration of total microbial counts of mesophilic aerobic microorganisms and separately of Pseudomonas spp by ISO methods. Results: 10-HSA has a common linear positive correlation with bacterial counts for all three studied meats with R2 = 0.96 between 1 and 8 or 11 days. This phenomenon suggests the presence of various bacteria that may have slightly different slopes of the linear regression, the resulting correlation is a combination of these primary correlations. For Pseudomonas spp, there are separate positive linear correlations for all three meat types. Consequently, we can distinguish the meats by the slope of their regression line. Conclusion: These are the first encouraging results, but further research is needed to prove the suitability of 10-HSA as a novel marker of bacterial contamination of various meats.
Radka et al, 2021, J. Biol. Chem., 296, 100252. https://doi.org/10.1074/jbc.RA120.016818 Morello et al, 2019. Front. Microbiol., 10:1826. https://doi.org/10.3389/fmicb.2019.01826)

Keywords: bacterial contamination, markers, various meats, oleic acid oxygenation, 10-HSA, ruminants.

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Microbiological safety and quality of plant-based alternative products

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Abstract. This study aimed to assess the microbiological safety and quality of plant-based alternative products to animal-based foods. Samples were collected from the retail level in Estonia. As of October 2025, a total of 211 products have been analyzed. Microbiological analyses were performed in accordance with ISO standards in the laboratories of the Food Hygiene and Safety Unit of the Estonian University of Life Sciences (EMU). The analyses included the determination of counts of aerobic mesophilic microorganisms, yeasts and molds, Bacillus spp. and Bacillus cereus, Clostridium spp., and Escherichia coli, as well as the detection and enumeration of Listeria monocytogenes. Based on the results, the microbiological quality of the alternative products can be considered satisfactory, as the counts of mesophilic aerobic microorganisms, yeasts, and molds were generally low. However, approximately 15% of the samples contained Bacillus spp. in the range of 100-1000 CFU/g, and 5% contained more than 1000 CFU/g. Clostridium spp. were detected in about 15% of the meat alternative samples, but at low concentrations. Escherichia coli was detected in only a few samples, and L. monocytogenes was not detected in any of the analyzed products. The analyses are ongoing. In collaboration with LABRIS, the species composition of microorganisms present in the alternative products was investigated using the MALDI-TOF MS method. Strain identification revealed microorganisms that may represent previously unrecognized microbiological hazards in food, including Enterococcus faecium, Staphylococcus hominis, Staphylococcus warneri, Staphylococcus haemolyticus, Micrococcus luteus, Micrococcus endophyticus, Leuconostoc mesenteroides, Ochrobactrum intermedium, Bacillus circulans, Proteus vulgaris, Proteus hauseri, Streptococcus mitis, and others. Many of these are nosocomial pathogens, i.e., associated with infections acquired in hospitals or healthcare facilities. From a public health perspective, these findings can be significant, as such opportunistic pathogens can cause severe infections, particularly in individuals with weakened immune systems, including the elderly, children, and patients with chronic diseases, potentially increasing the incidence of foodborne illness. Moreover, it should be noted that Regulation (EC) No 2073/2005 of the European Commission, which defines microbiological criteria for food categories, does not currently establish food safety or process hygiene criteria for plant-based alternative products. In conclusion, there is a need to establish process hygiene and food safety criteria for alternative products in order to protect consumers, considering the growing popularity and market share of these products.

Keywords: Plant-based alternative products, microbiological safety, microbiological quality, opportunistic pathogens, public health.

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Use of Sunflower and Hemp Seed Proteins in Protein Bars: Effects on Physicochemical and Sensory Properties during Storage

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Abstract. The increasing demand for plant-based and environmentally sustainable protein sources has driven interest in alternative proteins for use in convenience foods such as protein bars. However, replacing animal-derived proteins with plant proteins remains challenging due to differences in functional properties affecting texture, stability, and sensory quality. This study investigated the feasibility of substituting whey protein with sunflower seed and hemp seed proteins in protein bars and evaluated the resulting changes in physicochemical and sensory properties during storage. Three types of protein bars were formulated using whey, sunflower seed, and hemp seed protein concentrates. The bars were stored at room temperature and analysed over a 28-day period (Days 1, 14, and 28). Physicochemical properties, including cutting resistance, pH, and moisture content, were measured in replicate. In addition, sensory evaluation was conducted to assess the influence of protein source on textural and flavour attributes. The results demonstrated that protein source significantly affected the quality characteristics of protein bars and their evolution during storage. Cutting resistance increased approximately sixfold in all samples by Day 14, reaching similar levels (~40–44 N), indicating pronounced structural firming during early storage. By Day 28, distinct differences between protein sources emerged: whey protein bars exhibited the highest cutting resistance (~46 N), while sunflower protein bars showed intermediate values (~39 N) and hemp protein bars the lowest (~30 N), indicating differences in structural stability over time. Plant protein bars consistently showed lower pH values (~5.4–5.8) compared to whey protein bars (~6.0–6.1), with a gradual decrease observed during storage, whereas whey-based bars maintained a higher and more stable pH. Moisture content remained higher in whey protein bars (~13%) than in plant protein bars (~11%) throughout the storage period, reflecting differences in water-binding behaviour between protein systems. Sensory evaluation indicated that protein source influenced texture-related attributes such as cohesiveness and stickiness, as well as flavour perception. Plant protein bars exhibited differences in mouthfeel compared to whey-based bars, reflecting the distinct functional properties of the proteins used. Overall, the findings suggest that sunflower seed and hemp seed proteins can be considered as potential alternatives to whey protein in protein bar formulations under the studied conditions. The observed differences in texture development and physicochemical stability highlight the importance of protein selection in product design. Lower cutting resistance, reflecting a softer texture, is often associated with higher consumer acceptability and may contribute to maintaining desirable product quality during storage. However, further optimisation of formulations and processing conditions is required to achieve consistent product quality.

Keywords: Plant-based proteins, Protein bar formulation, Physicochemical properties, Texture stability during storage, Sensory evaluation.

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Hypoxanthine and malondialdehyde as markers of minced pork quality. The effect of plant materials

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Abstract. Adenosine triphosphate (ATP) is the main energy-carrying molecule in living organisms. After slaughter, ATP is broken down into adenosine diphosphate (ADP), adenosine monophosphate (AMP), inosine monophosphate (IMP), inosine and hypoxanthine (Hx). AMP, IMP and Hx are, among others, important meat flavourings. Hx is chemically stable, because the level of the enzyme (xanthine oxidase) that breaks it down in pork is very low. Therefore, the content of Hx in the muscle increases over time and Hx can be used as a quality marker during the storage of ground meat. Another relatively stable marker of meat quality is malondialdehyde (MDA), a secondary product of unsaturated lipid oxidation. The aim of this study was to compare these two markers, which originate from both autolysis and bacterial activity. They were measured by the HPLC-DAD method during storage of fresh ground pork at refrigerator temperature with and without the addition of plant powders, for up to 14 days. The used plants were blackcurrant (Ribes nigrum L.), chokeberry (Aronia melanocarpa (Michx.) Elliott), rowan berry (Sorbus sp.), tomato (Solanum lycopersicum L.) and rhubarb (Rheum rhaponticum L.). In addition, the powders of garlic bulbs (Allium sativum L.) and apples were used (Malus domestica Borkh.) The samples were taken for analyses on days 1, 4, 6, 8, 11 and 14. The results demonstrated a strong positive correlation between the counts of aerobic microorganisms and both Hx and MDA in all treatments ($r_s > 0.76$, $p < 0.05$), except for apple and chokeberry in the case of MDA and rhubarb in the case of Hx; and strong positive correlations between Hx and MDA ($r_s > 0.81$, $p < 0.05$), depending on the added plant material – lowest in apple $r_s = 0.81$ and highest in tomato $r_s = 0.96$. Question is - How can these markers that come from very different degradation paths correlate so well? We propose two hypotheses to prove: I One way is through the breakdown of Hx by xanthine oxidase, which produces two hydrogen peroxide (H_2O_2) molecules and one uric acid molecule. Hydrogen peroxide can generate radicals boosting the oxidative degradation of polyunsaturated lipids, leading to the formation of MDA. II Another possible way is through the overall muscle degradation after the slaughter, when all degradation markers can be correlated over time. Research in this topic is ongoing.

Keywords: ATP degradation, malondialdehyde, hypoxanthine, plant powders in meat, food quality.

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Maximizing the Nutritional Value of Blackthorn Pomace Powder via Controlled Thermal Treatment and Fractionation

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Abstract. The valorization of blackthorn (Prunus spinosa L.) pomace into functional powders presents a sustainable strategy to recover valuable bioactive compounds typically discarded after juice extraction. This paper aimed to investigate the impact of drying temperature and fractionation on the nutritional profile of blackthorn pomace, as well as to optimize these parameters. The proximate composition was assessed using international standard methods. The fatty acid profile was determined by using a Shimadzu GC-MS spectrometer. The mineral composition was analyzed using a Shimadzu AAS-6300 atomic absorption spectrophotometer. Using Design Expert (trial version), an I-optimal Response Surface Methodology design modeled the interactions between the numeric factor (Temperature: 45, 55, 65 °C) and the categorical factor (Particle Size: S, M, L). A quadratic model and the desirability function were used for optimization, with subsequent ANOVA and Tukey's mean comparison. The responses considered were: protein, lipids, ash, carbohydrates, polyunsaturated fatty acids (PUFA), atherogenic index (AI), Zn, and Fe content. The optimization constraints were defined to maximize PUFA and minimize both carbohydrates and the AI, while maintaining temperature, particle size, and all other nutritional parameters within their experimental ranges. The results showed that particle size reduction led to higher protein, lipid, and ash content of the blackthorn pomace, while the increase in temperature resulted in an increase in these nutrients, except for the lipid content for the L fraction. Carbohydrates increased up to 55 °C, then decreased as a result of the intensification of browning and Maillard reactions. M particle size presented the highest carbohydrate content, followed by S and L. A reduction of PUFA was observed as the temperature was higher, and the L fraction presented the lowest value. For S and M samples, the AI decreased with temperature increase, while for the L fraction, the opposite trend was observed. The lowest AI was obtained for the S fraction. Zn and Fe content decreased with temperature increase, while M fraction presented the highest values, followed by S and L. Temperature factor significantly influenced ($p<0.05$) all the parameters, except for the lipid content. Particle size factor had a significant impact ($p < 0.05$) on the characteristics studied, except for carbohydrates and PUFA, whereas the interaction between factors was non-significant ($p>0.05$) for lipids, carbohydrates, and PUFA. The quadratic models proposed were suitable for data prediction since the R2 values ranged from 0.87 to 0.99 ($p<0.05$). The optimization revealed that at 65 °C for the S fraction, lipid and protein contents were maximized, whereas at 65 °C for the M fraction, a more balanced nutrient profile was observed. In contrast, the lowest temperature of 45 °C for the L fraction favored higher carbohydrate and mineral (Zn, Fe) contents, highlighting a trade-off between macronutrient enrichment and micronutrient accumulation. In conclusion, controlled drying treatment combined with fractionation can unlock the full nutritional potential of blackthorn pomace. Optimized processing preserves bioactive compounds, enhances antioxidant activity, and generates multiple fractions suitable for functional food or nutraceutical development, contributing to waste valorization and sustainable food production.

Keywords: Particle size, circular economy, thermal treatment conditions, optimization, nutritional profile.

X LIVESTOCK TECHNOLOGY

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Adverse effects of heat stress on behaviour and milk traits of Austrian Fleckvieh cows

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Abstract. Heat stress in dairy cattle is a growing health and welfare issue as a result of climate change. Calculating the average daily temperature humidity index (THI) could potentially underestimate heat stress levels in dairy cows. When assessing heat stress levels in cows, it's important to consider the duration and intensity of heat load to avoid underestimating the actual heat stress experienced by the dairy cattle. We investigated the effect of different levels of heat load duration and intensity on Austrian Fleckvieh lactating cows' behaviour responses and production performance. The milk and behaviour data sets included 507 and 132 Austrian Fleckvieh dairy cows respectively, which were obtained between June and September 2020. THI thresholds were set to 68 or 72 for calculating daily heat stress duration in hours. For estimating the effects on milk traits, heat stress levels were defined by the calculated value of the total hour duration above THI threshold within a 3-day period. For estimating the effects on behaviour, the effects of heat stress on 1 to 3 days prior to the milk testing day were examined. Previous models used only mean THI or duration to estimate heat stress, which would have underestimated its negative effects on cows. Both behaviour and milk production were negatively affected by cumulative effects of heat stress over at least three days. Prior to the milking day, an increase in heat exposure and intensity resulted in an increase in daily standing time, a decrease in daily lying time, and reduced milk output and milk protein content. The milk yield of high-yield cows in early lactation and the milk protein were particularly sensitive to heat stress.

Keywords: Fleckvieh lactating cow, heat load, temperature humidity index, behaviour, milk production.

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Toward Dependable Communication for Precision Livestock Farming: A Multi Technology Framework Informed by Measurements and 6G Trends

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Abstract. Livestock farming increasingly relies on digital solutions that demand dependable and high-performance wireless communication capable of supporting dense, heterogeneous Internet of Things (IoT) deployments in rural environments. In this paper, we report results obtained in the ET4D project, departing from analysis and extensive measurements of wireless communication performance in smart livestock barns across several European countries. The study identifies key obstacles affecting today's connectivity infrastructures, including sparsely deployed cellular networks, complex farm building geometries, severe penetration losses caused by concrete and metal structures, terrain-induced coverage holes, and limited uplink capacity for high-density sensor deployments. Building on these results, we analyse communication bottlenecks impacting core applications such as livestock health and behaviour monitoring, automated milking and feeding systems, pasture scale tracking, and environmental sensing. Our findings show that no single technology—LPWAN, LTE/4G/5G, Wi-Fi, satellite, or even emerging 6G early-prototype features—can independently meet the full set of requirements across range, energy efficiency, reliability, latency, mobility, and scalability. Instead, digital livestock farming requires a carefully integrated, multi-connectivity approach that ensures interoperability across diverse radio technologies and remains robust under variable environmental conditions. In this context, upcoming 6G capabilities such as intelligent surfaces, precise localisation, and integrated sensing communication will become critical enablers for next-generation farm automation, but only when combined coherently with existing systems. We further evaluate practical enhancement strategies derived from the identified shortcomings. These include high-gain directional antennas for outdoor cellular capture, optimised antenna placement and alignment informed by field measurements, repeaters for extending cellular coverage into shielded indoor spaces, cabling-based outdoor-to-indoor signal routing, and hybrid indoor distribution using Wi-Fi or Low Power Wide Area Network (LPWAN) to support heterogeneous IoT traffic classes. Additionally, we outline design principles for scalable and future-proof deployments capable of accommodating growing device populations, increased data rates, and the machine learning driven automation expected to intensify with 6G adoption. Our results demonstrate that combining these measures into a coherent, layered connectivity framework enables substantial improvements in communication dependability, coverage continuity, and overall network performance—even without large scale infrastructure upgrades. This supports more robust operation of mission critical systems such as real time health monitoring, automated milking, and environmental control, which are essential pillars of precision livestock management. The work thus provides both a quantitative evidence base and a practical roadmap for improving IoT connectivity in digitalized dairy and livestock farms, preparing them for an efficient, transparent, and sustainable data driven future increasingly aligned with the capabilities of emerging 6G-era connectivity and data management ecosystems.

Keywords: IoT Connectivity; Livestock Farming; Rural Wireless Networks; Multi-Connectivity; 6G.

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XI PRECISION AGRICULTURE

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Analysis of bee pollen productivity and chemical composition

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Abstract. Honey bee pollen is a natural product with a rich mineral composition. The aim of the study is to analyze the factors affecting pollen productivity, its chemical composition and potential applications. Latvia, the quality of honey and beeswax has been studied, but the chemical composition of pollen is described using studies by scientists from other countries. Pollen yield from the hive and its chemical composition (Fe, Cr, Ca, K, Mg, Se) were determined over a three-year period in Latvia and Bulgaria. The foraging activity of honeybees from different hives varied, so the number of pollen samples differed. Honeybees collected pollen in pollen collectors from 9:00 to 20:00. Each pollen collector was thoroughly cleaned after each use to avoid cross-contamination of samples. Pollen was weighed with precision of 0.1 g, dried at 40o C, and labelled with date, time, hive number, and study location. Bee pollen yield ranges from 0.5- 2 kg per colony, depending on the location of collection, variety of blooming flowers, and weather conditions. This is reflected in the significantly higher average daily yields of two colonies (103.6 g and 108.8 g) compared to 2023 and 2025. The calcium content in the pollen dry matter of the average sample is 1465 ± 146 mg kg-1 (in Latvia), 720 ± 2 mg kg-1 (in Bulgaria), potassium content 5373 ± 537 mg kg-1 (in Latvia), 3776 ± 377 mg kg-1 (in Bulgaria), magnesium content - 1022 ± 102 mg kg-1 (in Latvia), 601 ± 60 mg kg-1 (in Bulgaria). The differences are explained by the duration of the plant's flowering, the variety of flowers and geographical location.

Keywords: bees, chemical composition, food, pollen, productivity.

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Assessment of common bean responses to light spectral composition and microbial inoculation using non-destructive methods

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Abstract. Non-destructive methods are increasingly used to evaluate plant physiological status. This study assessed the applicability of spectrometry and chlorophyll fluorescence for monitoring common bean (Phaseolus vulgaris) responses to light quality and microbial seed inoculation. A two-factor growth chamber experiment was conducted using LED lighting of equal intensity but different red-to-blue ratios (1:1, red-dominated, blue-dominated) and seeds that were either uninoculated or inoculated with Rhizobium phaseoli strains or Proseed-Met. Non-destructive measurements were performed on the same leaves using a spectroradiometer RS-3500 and a FluorPen FP110 fluorometer. Vegetation indices were calculated to evaluate stress, pigment content, senescence, and water status, while fluorescence parameters described photosynthetic performance. Spectrometric indices more clearly reflected light treatment effects, showing higher pigment content under red light, greater senescence under balanced light, and increased stress under red-dominated spectra. Fluorescence parameters were mainly affected by microbial inoculation and were higher in inoculated plants. Limited correlations between the two methods indicated that they capture different aspects of plant physiology. Blue-dominated light increased pod number, whereas red light reduced pod and seed mass. Microbial inoculation alone did not significantly affect yield, but the highest seed yield was observed in Rhizobium-inoculated plants under blue light. The results highlight the importance of light spectral composition for bean productivity and support the combined use of spectrometric and fluorescence methods for comprehensive physiological assessment.

Keywords: chlorophyll fluorescence, LED, Phaseolus vulgaris, spectrometry, vegetation indices.

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Crop system impact on ammonium transporters activity in Field Pea

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Abstract. Nitrogen is a macronutrient required for plant adequate growth and yield formation. Nitrogen use efficiency (NUE) differs among cultivars, species, and land management practices, due to differences in nitrogen form availability and plant utilization strategies. In legume-based systems such as field pea (Pisum sativum L.) which uses also symbiotically fixed N2, the nitrogen dynamics is more complicate. To better understand the nitrogen use in field pea; this work aims to evaluate the expression of ammonium transporters (LeAMT) under different nitrogen sources and levels. Field pea samples from a long-term crop rotation field experiment were collected in July 2025 from two conventional systems—N0 (N0, P0, K0) and N20 (N20P25K95)—and two organic systems—Org0 (no fertilizer or pesticides) and OrgII (catch crop plowed before pea sowing + cattle manure (90 Nmin) applied early fall before winter wheat). Shoot samples were collected at two phenological stages, BBCH61 (full flowering) and BBCH71-73 (pod filling). RNA extraction was performed using the RNeasy® Plant Mini Kit (QiaGen), following the manufacturer's protocol. cDNA was synthesized with FIREScript® RT cDNA synthesis MIX with oligo (dT) (SolisBiodyne). Real-time PCR was performed using the Rotor-Gene® Q with HOT FIREPol®, EvaGreen® and qPCR Supermix (SolisBiodyne) and relative expression levels were calculated against the Org0. Seed's protein content was analysed by GrainSense®. Yield is presented as g/20 m². Total nitrogen and carbon of dried shoot was determined using the Primacs SNC-100® elemental analyzer. The data was submitted to ANOVA ($p < 0.05$) and the differences between means were assessed with LSD ($p < 0.05$). The expression of LeAMT at both growth stages showed variation, but no statistically significant differences were observed ($p < 0.05$). Both LeAMT levels varied in the same direction between treatments, with higher expression values at N0 and lower at OrgII. When comparing N0 vs. N20, AMT1 and AMT2 showed the greatest differences, respectively: 46% and 37%. In contrast, the smallest differences were observed between N0 vs. OrgII: 30% for AMT1 and 16% for AMT2. AMT1 expression was similar between two sampling times (0.52 and 1.04), while AMT2 showed significantly higher expression (1.77) at BBCH61 when compared to BBCH71-73 (0.37). This could mean field pea higher N need at flowering stage. But in addition, AMT2 expression showed a strong negative correlation ($r=-0.90$) with air temperature and precipitation, giving higher expression of AMT2 at lower air temperature and precipitation. LeAMT expression was not correlated with pea grains yield or protein concentration, which both were highest at OrgII, (650 g/20 m² and 28.17% respectively), following N20 (405 g/20 m² and 23.83%, respectively). Still at N0 both LeAMT expression was higher but grain yield and protein concentration showed the lowest values. Was possible to observe a positive correlation between C% and AMT1($r = 0.81$) and AMT2 ($r = 0.88$) expression which can be connected with plant growth. To gain further insight, additional analyses are necessary, such as evaluating nitrate transporters and amide concentrations in the plant.

Keywords: LeAMT expression, Field Pea, Pisum sativum L, Nitrogen.

Acknowledgements. This work was supported by the Estonian Research Council grant PRG1949.

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Integrated Management of Nondestructive Sensing of Moisture Content in Grain: A Digital Agriculture Solution

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Abstract. Accurate determination of grain moisture is critical for fair pricing, safe storage, and preventing post-harvest losses. This study aims to develop a smart, nondestructive, and real-time moisture measurement system using the microwave resonant method at 2.45 GHz, integrated with an Internet of Things (IoT) infrastructure and machine learning algorithms for dynamic calibration. The system architecture features a microstrip ring resonator designed on an FR4 substrate, operating at a resonance frequency of approximately 2.45 GHz. An original RF card, functioning as a custom Vector Network Analyzer (VNA), was developed and integrated onto the same circuit board as the resonator to minimize calibration errors and signal loss. The system measures the transmission coefficient (S21), from which signal attenuation (A) and phase shift (f) are derived to calculate the complex relative permittivity components (ε′ and ε″). The measurement unit calculates the transmission coefficient (S21), resonant frequency shift (Δf), and bandwidth change (Δw) when a grain sample is placed in the cavity. To process and manage the measurements, an IoT architecture comprising an MQTT broker, a web server, and a MySQL database was implemented. This infrastructure enables wireless data transfer, real-time remote monitoring, and cloud-based computation. The system was experimentally tested on various grain types, including rice, wheat, and chickpeas, which were conditioned to multiple moisture levels. Several machine learning algorithms, including k-Nearest Neighbors (kNN), Random Forest (RF), and Multilayer Perceptron (MLP), were evaluated to predict the moisture content independent of physical properties such as bulk density. The electromagnetic simulations and empirical measurements of the microstrip ring resonator demonstrated a strong resonance near 2.45 GHz, providing high sensitivity for moisture detection. The machine learning models successfully predicted the moisture content with high accuracy. Specifically, the kNN and RF algorithms outperformed others, yielding correlation coefficients (R) greater than 0.98 for wheat. The kNN algorithm exhibited the best variance alignment and the lowest mean absolute error (MAE), proving to be highly robust for modeling the nonlinear relationship between dielectric properties and moisture content. In conclusion, the developed microwave resonant sensor, combined with machine learning and IoT technologies, provides a cost-effective, scalable, and highly accurate digital agriculture solution for measuring grain moisture.

Keywords: Grain moisture content, Microwave resonant technique, Nondestructive measurement, Machine learning, Digital agriculture.

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Changes in Protein Content in Genotypes of Common Beans (Phaseolus vulgaris) Grown in Latvia

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Abstract. Common beans (Phaseolus vulgaris L.) are among the world's most important legumes, cultivated in both tropical and temperate climates. They originate from two genetic centres—the Andes and Mesoamerica—where their domestication began before spreading globally. Nutritionally, they are valuable for their high content of proteins, dietary fibre, B vitamins, and mineral elements, especially iron and potassium. The objective of this study was to examine changes in protein content in the seeds of common bean (Ph. vulgaris) genotypes grown under agrometeorological conditions of Latvia. Field and vegetation pot experiments were conducted from 2023 to 2025 using 28 genotypes obtained from six local growers, along with twelve additional genotypes supplied by INCREASE project partners in the frame of the Citizen Science Experiment. The cultivars 'Sundance' and 'Meccearly' were included as a reference genotype for comparative evaluation. Genotypes were phenotypically characterised, and seed protein content was determined using the Kjeldahl method. The examined genotypes varied in yield and yield stability. Genotypes received through the INCREASE project exhibited higher yields than Latvian genotypes but had later maturation times. The weight of 100 seeds ranged from 13.5 g to 86.6 g ('Meccearly'). The highest protein content among locally grown beans was recorded in 2024, in genotype LV03 (31.4%), the lowest one in average in the seeds of cultivar 'Meccearly'. Although smaller seeds tended to show higher protein levels, statistical analysis did not support this pattern (correlation coefficient -0.164). A strong positive correlation was found between protein content and the accumulated sum of active temperatures (correlation coefficient 0.950), indicating that thermal conditions play a key role in protein accumulation in common bean seeds grown in Latvia.

Keywords: seed, maturation, quality.

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Biochemical properties and morphological variability of fruits of interspecies hybrids of Cucurbita genus

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Abstract. Interspecific hybridization of Cucurbita species is an effective approach for developing forms with enhanced nutritional value, morphological diversity, and improved stress tolerance. This study aimed to characterize the morphological and biochemical traits of physiologically ripe fruits of interspecific hybrids between squash (C. pepo) and pumpkin (C. maxima), derived from 'Patriot F1' and 'Defender F1' crossed with the Ukrainian variety 'Narodnyi'. The research was conducted in 2025 in Latvia and Ukraine. Morphological analysis revealed considerable variation in fruit shape (from cylindrical to pear–shaped and spherical) and skin color, ranging from typical squash patterns to pumpkin–like forms. Fruit weight in Latvia varied widely (0.40–6.56 kg), whereas in Ukraine it was more uniform, likely reflecting different environmental pressures. Biochemical profiling of physiologically mature fruits also showed pronounced genotypic and environmental variability. Total soluble solids (°Brix) ranged from 1.7–4.6% in Latvia and 3.42–5.0% in Ukraine, differences that may be linked to temperature and moisture conditions influencing sugar accumulation. Phenolic compounds ranged from 9.75 to 26.45 mg GAE g-1 and flavonoids from 0.13 to 1.25 mg CE g-1 FW, with the highest antioxidant levels in the variety 'Narodnyi' and the (Defender F1 × Narodnyi) hybrid, suggesting preserved or enhanced antioxidant capacity. β-carotene content varied between regions (0.38–0.92 mg g-1 in Latvia and 0–1.48 mg g-1 in Ukraine), peaking in backcross generations (BC_1), which may reflect reinforcement of pumpkin-type traits and photoprotective responses. Vitamin C levels showed similar regional differences (10.55–16.68 mg g-1 in Latvia; 7.14–13.61 mg g-1 in Ukraine), likely influenced by temperature and solar radiation. Dry matter in Ukrainian hybrids ranged from 4.34 to 6.83%, highest in Patriot BC1 and Defender BC1, indicating partial reversion to C. maxima characteristics associated with greater structural and reserve biomass. The results demonstrate a significant influence of both genotype and growing environment on the formation of the biochemical composition of fruits in interspecific hybridization of C. pepo × C. maxima. The results confirm the promise of hybrids for use in food production technologies, as well as their potential stress resistance due to the combination of genetic resources from squash and pumpkin.

Keywords: abiotic stress, β-carotene, dry matter, flavonoids, genotypic variability, hybrid forms, pumpkin, squash, vitamin C.

Acknowledgements. The authors sincerely thank the Latvia University of Life Sciences and Technologies for conducting biochemical analyses in the frame of project "Strengthening the Institutional Capacity of LBTU for Excellence in Studies and Research", funded by The Recovery and Resilience Facility" and providing experimental data obtained in their agroclimatic conditions. This work was supported by the projects "Development of an express method for early detection of plant stress and enhancement of stress tolerance" (EXPLORERS, No. 1.1.9/LZP/2/25/196).

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Autonomous Variable-Rate UAV Spot Spraying using CDA Nozzles and Dual Deposition Sensing

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Abstract. This study presents the development and testing of an autonomous precision spot-spraying system for unmanned aerial vehicles, aimed at optimizing both the amount and spatial distribution of applied herbicides. The system is implemented on a consumer-grade multicopter platform originally designed for uniform spraying without variable-rate capability, which is retrofitted with a modular spraying unit incorporating a controlled droplet application (CDA) nozzle and custom control architecture. This architecture interfaces directly with the flight controller to synchronize spray parameters with the instantaneous flight path and forward velocity of the drone. System verification and performance evaluation play a central role in the study. Spray deposition and spatial accuracy are assessed using two complementary measurement approaches. Water-sensitive indicator papers are deployed across the target area to provide qualitative and semi-quantitative information on droplet coverage and spatial distribution, enabling detailed characterization of the spray pattern both within and outside treated spots. In parallel, a resistance-based sensor array, conceptually analogous to rainfall sensors and designed and implemented as part of this research, is used to deliver continuous, real-time quantitative measurements of local spray deposition based on changes in surface conductivity as droplets accumulate on the sensor surface. The combined evaluation of these measurement methods provides an objective basis for validating and refining spot-spraying algorithms, as well as for assessing system responsiveness and control accuracy. From an application perspective, the primary goal of the developed system is its integration into precision farming workflows, specifically in herbicide applications where weed presence is the primary trigger However, it is noted that for insects or diseases, additional layers of decision-making, such as economic injury thresholds, would be required to justify application. By enabling accurate identification and targeted treatment of specific zones, the system reduces unnecessary chemical usage and off-target losses, thereby lowering environmental impact while improving the efficiency and sustainability of drone-based plant protection.

Keywords: UAV, autonomous, spot-spraying, variable-rate herbicide application, precision agriculture.

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Tomato growth, nutrient dynamics and yield in response to a fermented grass-based liquid fertilizer in peat-based substrate

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Abstract. Sustainable horticultural production increasingly relies on renewable nutrient sources in order to reduce the use of conventional mineral fertilizers. Fermented grass biomass can be used to produce liquid fertilizers suitable for greenhouse tomato cultivation; however, their effects on nutrient availability and crop performance in peat-based substrates are still insufficiently understood. The aim of this study was to evaluate the effects of a grass-derived liquid fertilizer, applied at increasing rates, in comparison with conventional mineral fertilization on plant growth, nutrient dynamics and yield of tomato (Solanum lycopersicum L., cv. 'Betalux'). The experiment included a conventional mineral fertilization control and four liquid fertilizer treatments (T1–T4). Nutrient concentrations in the substrate and plant leaves were monitored throughout the growing season, together with yield parameters and the SPAD chlorophyll index. Conventional fertilization resulted in the highest total yield (1545.6 g plant^{-1}), fruit number (40 fruits plant^{-1}) and a stable nutrient status. Among the liquid fertilizer treatments, T3 performed best, producing 1224.4 g plant^{-1} and 35.3 fruits plant^{-1}, corresponding to a 21% yield reduction compared with the mineral control, while mean fruit weight was only moderately lower. Lower application rates (T1 and T2) resulted in progressive depletion of nitrogen, phosphorus, calcium, magnesium, iron and boron in plant tissues and led to 25–27% lower yields. In contrast, excessive application of liquid fertilizer (T4) caused substrate acidification and elevated electrical conductivity, resulting in salt accumulation, impaired nutrient uptake and the lowest yield (798.1 g plant^{-1}), despite producing the largest fruits (42.85 ± 2.06 g). Molybdenum uptake was strongly influenced by substrate pH rather than by total Mo content, whereas zinc, copper and manganese concentrations remained relatively stable. Overall, the results indicate that grass-derived liquid fertilizers can support tomato nutrition in peat-based systems only within a limited application range. Careful dose management or partial supplementation is required to avoid nutrient deficiencies at low application rates and salinity-induced yield losses at excessive rates.

Keywords: Organic fertilization, nutrient uptake, greenhouse cultivation, SPAD index, tomato yield.

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Comprehensive assessment of genotype–environment interaction and trait associations in sugar beet hybrids under short-rotation cropping systems of the Western Forest-Steppe of Ukraine

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Abstract. This study aimed to evaluate genotype × environment (G×E) interaction, phenotypic stability, and multi-trait performance of sugar beet (Beta vulgaris L.) hybrids under short-rotation cropping systems of the Western Forest-Steppe of Ukraine. Eight commercial hybrids were tested across four environments (two locations over two years) using a randomized complete block design. Root yield (RY), sugar content (SC), sugar production (SP), impurity-related traits, and derived technological indices were analyzed using combined ANOVA, AMMI modeling, and BLUP-based stability metrics. Environmental effects were the dominant source of variation for RY, SC, and SP, while genotype and G×E interactions were smaller but statistically significant, confirming differential hybrid responses to contrasting environments. Stability was assessed using AMMI stability value (ASV), weighted average of absolute scores (WAASB), and the joint yield–stability index (WAASBY). BTS 9695, Strube Hubble, and KWS Ladislava consistently combined high mean productivity with low instability, indicating broad adaptation. Multi-trait evaluation using genotype by yield × trait (GYT) analysis revealed clear trade-offs between yield and technological quality. Hybrids BTS 9695 and Strube Hubble showed superior combinations for RY × SC and RY × low impurities, indicating high sugar productivity without major quality penalties. Overall, the integrated AMMI–WAASB/WAASBY–GYT framework proved effective for identifying sugar beet hybrids that combine high productivity, stability, and technological suitability under variable agroecological conditions, providing a robust basis for breeding and production recommendations.

Keywords: adaptability, AMMI, genotype × environment interaction, GYT-biplot, stability analysis, sugar beet.

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Optimization of nitrogen, phosphorus, and potassium fertilization for maximizing root yield and inulin yield in chicory (Cichorium intybus L.)

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Abstract. Root chicory (Cichorium intybus L.) is an important industrial crop for inulin production, but the optimization of mineral fertilization under fertile chernozem soils remains insufficiently defined. Under such conditions, additional fertilizer inputs may not proportionally increase root and inulin yield and may lead to higher residual nutrient levels after harvest. The aim of this study was to evaluate the effects of nitrogen and phosphorus-potassium fertilization on root biomass traits, crude inulin content, inulin yield, and post-harvest soil nutrient status of root chicory grown in the Right-Bank Forest-Steppe of Ukraine. A three-year field experiment (2021–2023) was conducted using a two-factor design with incremental PK and N rates. Cluster analysis and pairwise correlation coefficients were calculated between these parameters. The proposed approach to determining the optimal fertilizer rates for maximizing yield in individual years indicated values of N130P66K110, N150P60K100, and N120P72K120, with an average of N130P66K110. The highest inulin yield reached 5.80 t ha^{-1}, compared with 2.88 t ha^{-1} in the unfertilized control. Crude inulin concentration varied less than biomass-related traits, indicating that industrial raw material output depended primarily on root productivity rather than on large changes in inulin concentration alone. Post-harvest soil analysis showed that nitrogen fertilization increased residual hydrolysable nitrogen, whereas PK fertilization mainly increased mobile phosphorus at higher application rates. Thus, optimization of chicory fertilization under fertile chernozem conditions should be considered not only as a strategy for maximizing root and inulin yield, but a way to improve nutrient-use efficiency and avoid unnecessary nutrient surpluses.

Keywords: agro-ecology, cluster, correlation, model, nutrient.

Acknowledgements. This work was carried out within the framework of the research “Optimization of the Technology for Growing Inulin-Containing Crops for Raw Material Production for Alternative Energy Needs” (№ 0121U111237), which is part of the thematic plan of NUBiP. Studies on the effects of fertilizers on the residual content of nitrogen, phosphorus, and potassium in soil under chicory cultivation were conducted as part of the research project “Development of phytoremediation approaches for the production of safe products and for enhancing biodiversity and ecosystem resilience” (№ 0126U000991), funded by the Ministry of Education and Science of Ukraine.

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Soybean production potential in Estonia

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Abstract. Soybean is a widely cultivated protein crop globally, yet it is a novel crop in the Baltic States. The first scientific soybean trials in Estonia started in 2005. Farmers on the island of Saaremaa, where the climate is milder, tested varieties from The Czech Republic. Success led to the official soybean breeding program and the Estonian variety 'Laulema' was registered in 2014 along with the first cultivation recommendations. Soybean production expanded in 2015 and reached its peak in 2017, when 119.4 ha was planted. On-farm and certified seed-lot yields ranged from 176 – 784 kg ha^{-1}, whereas multi-year performance records kept by the Centre of Estonian Rural Research and Knowledge (METK) indicated a wider range. The yield has varied from 176 – 784 kg ha^{-1}, thousand kernel weight from 170.9 – 190.3 g, and protein content from 35.36 - 37.55%. Certified seed batches were produced only in 2015, 2016 and 2018. Although soybean was grown every year until 2024, the production has subsequently declined, and the crop has not secured a stable place in crop rotations. Soybean cultivation is constrained by a short growing season, the risk of spring and autumn frosts, suboptimal soil conditions, limited availability of varieties adapted to Baltic-Nordic environments, and difficulties in multiplication of the sole local variety 'Laulema'. Initial expectations were driven by expected climate change and rising temperatures. However, this present study, reviewing the efforts conducted over 20 years, shows that the region's still insufficient temperature sums, and excessively wet harvest seasons further restrict production. Overall, while soybean holds potential in the Baltic-Nordic region, its broader adoption will depend on future climate conditions, targeted breeding efforts, and agronomic solutions.

Keywords: Baltic region, high-latitude cropping systems, protein crops, soybean (Glycine max), yield variability.

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Bioaccumulation and Translocation of Heavy Metals in Pepper (Capsicum annuum) from Two Cultivation Zones in Kosovo

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Abstract. Heavy metal contamination in vegetables is a growing concern due to potential human health risks. This study evaluated the bioaccumulation and translocation of Pb, Cd, Ni, Fe, Cr, Cu, Zn, and Mn in pepper (Capsicum annuum) cultivated across 19 sites in two zones in Kosovo, including open fields and greenhouses. Soil, root, leaf, and edible fruit samples were collected, and metal concentrations were measured. Bioaccumulation factors (BAF) and translocation factors (TF) were calculated to assess metal uptake and movement within the plant. Metal accumulation varied between zones and cultivation systems. Pb and Cd in edible peppers generally remained below EU maximum limits (Pb: 0.1 mg/kg, Cd: 0.05 mg/kg), though several samples exceeded these thresholds, indicating localized contamination. Metals without regulatory limits (Ni, Cr, Fe, Cu, Zn, Mn) were compared with literature-reported background values; Ni, Cr, Cu, and Zn were elevated in multiple samples, suggesting environmental or anthropogenic influences. Bioaccumulation was highest in roots, with limited translocation to leaves and fruits for most metals, except Cu and Zn, which exhibited moderate movement. Open-field peppers generally accumulated slightly higher metal concentrations than greenhouse-grown peppers. Pb and Cd exceeded EU limits in several samples, while Ni, Cr, Cu, and Zn exceeded background levels in most samples. Mn and Fe remained largely within expected reference ranges. These results highlight the need for regular monitoring and targeted risk management for heavy metals in peppers, particularly in sites where concentrations surpass safe or reference levels.

Keywords: Keywords: Bioaccumulation, Translocation, Heavy Metals in Pepper, Kosovo.

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Climate Mitigation and Ecological Co-Benefits of Windbreaks: Carbon Sequestration Potential of Agroforestry Systems in Hungary

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Abstract. Land use plays a central role in achieving climate change mitigation targets, and a substantial share of its mitigation potential can be realized through agroforestry-based solutions integrated into agricultural production systems. Among these, windbreaks represent a long-standing and widely applied agroforestry practice in Hungary. From an agricultural engineering perspective, windbreaks function as structural landscape elements that interact with cropping systems by reducing wind erosion, regulating microclimatic conditions, and supporting soil conservation, while simultaneously delivering climate change mitigation benefits through carbon sequestration. Despite these functions, windbreaks and other trees outside forests are typically excluded from national greenhouse gas inventories, resulting in an underrepresentation of their contribution within land-use planning and climate policy frameworks This study addresses this gap by providing a quantitative assessment of the annual above-ground carbon sequestration potential of windbreaks across multiple spatial scales relevant to agricultural land management. Carbon sequestration was estimated at the national level, within two large-scale agricultural landscapes of approximately 24,000 hectares each, and at the farm scale on a 5-hectare organic agricultural holding. The multi-scale design enables evaluation of windbreak performance at both landscape-level infrastructure and on-farm levels within production-oriented agricultural systems. Methodologically, the study integrates in-situ field measurements with volumetric data from the National Forestry Database and orthophoto-based spatial mapping of windbreak networks. Field measurements characterized tree dimensions and species composition, while database-derived volumetric information supported biomass estimation. High-resolution orthophotos enabled the precise delineation and spatial quantification of windbreaks embedded within agricultural land. All calculations followed IPCC guidelines to ensure methodological consistency and compatibility with greenhouse gas accounting approaches used in land-use and agricultural reporting systems. The results indicate that Hungarian windbreaks collectively sequester an estimated 33.1 kt CO_2 per year in above-ground biomass. This corresponds to approximately 0.67% of the annual above-ground CO_2 removals attributed to all Hungarian forests. Notably, this contribution is achieved while windbreaks occupy only around 0.5% of the country's forest land area, highlighting their disproportionately high mitigation efficiency relative to land cover. The mean annual sequestration rate was estimated at 2.4 t CO_2 ha^{-1} $year^{-1}$ for the 2010–2020 period, which is comparable to average per-hectare sequestration rates reported for forest ecosystems. These findings demonstrate that windbreaks can deliver climate change mitigation benefits equivalent to those of forest land on a per-area basis, while remaining fully integrated within productive agricultural landscapes. In addition to carbon sequestration, windbreaks support biodiversity, improve microclimatic conditions for crops, and enhance soil protection, thereby contributing to the resilience and sustainability of agricultural systems.

Keywords: agroforestry, carbon sequestration, windbreaks, woody shelterbelts, mitigation.

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Bee colony weight dynamics during passive wintering period

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Abstract. Honeybees (Apis mellifera) are essential for maintaining ecological balance and enhancing agricultural productivity through their pollination services. Gaining insight into the internal conditions of a honeybee colony is crucial for evaluating its health, productivity, and seasonal dynamics. In the northern countries bee colony activity is divided into two periods: active summer and winter passive periods. Monitoring the weight of honey bee colonies provides valuable insight into their physiological status, food consumption, and survival potential during wintering. This study investigates the weight dynamics of bee colonies throughout the passive wintering period, aiming to better understand colony metabolism and resource utilization under low-activity conditions. Continuous weight measurements were recorded using electronic hive scales. The data were analysed to assess temporal trends in colony mass loss and to identify environmental or management factors influencing these changes. Results showed a gradual decrease in hive weight corresponding to the consumption of stored honey, with the rate of loss varying in response to external temperature fluctuations and colony strength. These findings contribute to improving winter management practices by providing quantitative parameters of weight consumption for assessing colony health and predicting overwintering success.

Keywords: bee colony weight dynamics, honeybee colony monitoring, passive wintering period, precision apiculture, precision beekeeping.

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Accumulation and yield formation in potato across controlled and field experiments: implications for nitrogen use efficiency research

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Abstract. Potato (Solanum tuberosum L.) productivity is strongly influenced by nitrogen (N), which regulates plant growth, biomass formation and tuber development. This study aimed to evaluate nitrogen accumulation and its relationship with biomass and yield, and to verify nitrogen use efficiency (NUE) assessment by comparing field trials with pot and in vitro experiments. Field experiments were conducted in Priekuļi, Latvia, under organic (OF) and integrated (IF) farming systems and in vitro experiments under controlled conditions. Pot trials were carried out in Jelgava. Three varieties ('Monta', 'Prelma', 'Jogla') were tested. Nitrogen was applied at 60 kg N ha^{-1} in IF field plots; pots received 60 and 120 kg N ha^{-1}, while in vitro treatments included 7.5, 20 and 60 mmol L^{-1} N. Nitrogen content in tubers was significantly affected by growing year and variety in both field systems ($p < 0.05$), with a significant year × variety interaction in OF. 'Prelma' consistently showed the highest nitrogen content, whereas 'Jogla' had the lowest across systems. Yield varied substantially among years and cultivation systems. In IF, 'Jogla' produced the highest yield, while in OF 'Prelma' performed best; 'Monta' had the lowest yields in both systems. In pot experiments, the highest yield was obtained at 120 kg N ha^{-1}, particularly for 'Jogla'. Nitrogen use efficiency (NUE) decreased with increasing N rate. The relationship observed under field conditions that earlier-maturing varieties have lower NUE than later-maturing ones could not be confirmed in the in vitro and pot experiments. Overall, consistent varietal responses across systems indicate that controlled-environment methods can support NUE evaluation in potato research.

Keywords: in vitro, integrated farming system, organic farming system, pot experiment, Solanum tuberosum.

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Development and Performance Evaluation of a Deep Learning-Based Autonomous Regional Spraying System in Apple Orchards

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Abstract. In this study, an artificial intelligence (AI)-supported regional spraying system was developed and compared with a traditional turbo atomizer to enable more precise, economical, and environmentally friendly calcium applications in apple orchards. Within the scope of the project, standard valves were replaced with solenoid valves, and a PLC-based control panel operating at 12 V was designed to provide synchronous, stable, and real-time control for a total of 16 nozzles. Thanks to the deep learning-based decision mechanism, selective spraying was applied in target areas, and the system's open/closed nozzle statuses were monitored with timestamps. Field applications were conducted under real production conditions on Golden Delicious and Scarlet Spur varieties. Water-sensitive cards were placed in the lower, middle, and upper canopy regions during the trials; spray quality parameters, including coverage rate, droplet number per unit area, droplet diameter, and droplet volume, were determined using image processing. The findings showed that the AI-supported system provided more homogeneous coverage in target areas and maintained more controlled droplet density in non-target areas. The reduction in variation in the upper canopy region was particularly noteworthy. In Scarlet Spur and Golden Delicious varieties, the AI-supported application reduced the coverage rate, droplet volume, and droplet diameter. A liquid savings potential of approximately 87.53 L/da (58.35%) was determined for both varieties. In contrast, no statistically significant deterioration was observed in droplet count and droplet density. In conclusion, the developed AI-supported regional spraying system stands out as a promising precision agriculture technology that reduces chemical use and environmental impact while maintaining target delivery.

Keywords: Deep learning, autonomous spraying, apple orchard, spray characteristics, digital agriculture.

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Optimizing Mycelium-Bound BioPCM–Wood Composites for Low-Impact Thermal Building Materials

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Abstract. The increasing demand for sustainable bio-based building materials with improved energy performance highlights the need for solutions that have a low environmental impact and functional properties such as latent heat storage. One approach is the integration of bio-based phase change materials (bioPCMs) into lignocellulosic composites, using fungal mycelia as a natural binder in place of synthetic adhesives to reduce the potential release of harmful and carcinogenic chemical compounds. The objective of this research is to identify the optimal combinations of wood substrates and fungal species that maximize mechanical strength while accommodating high bioPCM loading for effective thermal energy storage. To investigate this, wood particles and fibers composed of bioPCM-impregnated pine and spruce, together with non-impregnated birch, pine, and spruce, were prepared. Five white-rot fungi, Bjerkandera adusta, Hirschioporus abietinus, Lentinula edodes, Pleurotus eryngii, and Trametes versicolor, were evaluated as natural binding agents. The substrates and fungi were mixed into composites supplemented with wheat bran, potato starch, calcium carbonate ($CaCO_3$), and water, then incubated for 2–5 weeks under room-temperature, high-humidity conditions to promote full mycelial colonization. All fungal species successfully produced coherent, well-bound composites. Up to 75% bioPCM-impregnated wood substrate could be included in the mixture while still achieving composite formation. The low density and semi-structural properties of the composites make them suitable for internal cladding. These fully bio-based products are energy-efficient, environmentally responsible, and demonstrate strong potential to support low-impact, thermally optimized building design.

Keywords: Mycelium-based composites, Lignocellulosic bio-composites, Bio-based phase change materials, Thermal energy storage, Sustainable building materials.

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