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INTRA-POPULATION VARIABILITY OF THE MAIN MORPHOLOGICAL TRAITS OF *LOLIUM PERENNE* SPECIES

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Abstract

Lolium perenne L. is a key perennial forage grass in temperate regions, valued for its high productivity, nutritional quality, and adaptability for pastures, hayfields, silage, and lawns. In the context of climate change, breeding programs increasingly focus on developing cultivars with improved persistence, stress tolerance, and stable yields. These objectives rely on the availability of genetically diverse germplasm and the identification of superior parental material.This study evaluated 15 local and foreign genotypes of Lolium perenne, including varieties, breeding lines, and populations under homologation, to identify valuable sources for future cultivar development. The experiment was conducted at the Research and Development Institute for Grasslands, Braşov, during 2023–2025, using a field trial with 540 individual plants. In the third year (2025), morphological and phenological traits were recorded, including heading date, plant growth habit, vegetative and generative tillering, plant height, flag leaf dimensions, spike length, seed weight, and rust resistance. Data were analyzed using correlation analysis and principal component analysis (PCA). Significant variability was observed among genotypes for all traits. High productivity was associated mainly with increased generative tillering and favorable flag leaf characteristics, while plant height had a limited effect on reproductive performance. Strong correlations were identified between vegetative and generative tillering and between flag leaf traits and yield components. PCA showed that the first two principal components explained 74.86% of total variation. Genotypes such as Barnhem, Barsprinter, and Troian exhibited superior agronomic performance and represent valuable parental material for breeding programs. The results highlight the importance of multivariate analysis in germplasm evaluation for developing improved Lolium perenne cultivars adapted to future environmental challenges.

Keywords: *climate change, flag leaf traits, forage grasses, genetic variability, germplasm evaluation, Lolium perenne, principal component analysis*

EVALUATION OF THE PRODUCTIVITY VALUE OF NEW APPLE CLONES BRED AT THE NATIONAL INSTITUTE OF HORTICULTURAL RESEARCH

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Abstract

Based on the apple breeding programs conducted at International Institute of Horticultural Research, Skierniewice, Central Poland, we have selected 17 new apple breeding clones: J-2002-21-01 ('Rubin' x 'Gold Milenium'), J-2002-12-02 (J-79 x 'Rubin'), J-2002-05 ('Melfree' x J-79), J-2002-25-01 ('Sawa' x 'Rubin'), J-2003-04 ('Free Redstar' x 'Sawa'), J-9805-03 ('Braeburn' x 'Pinova'), J-2003-11-01 ('Gold Milenium' x 'Szampion'), J-9805-02 ('Braeburn' x 'Pinova'), J-9805-01 ('Braeburn' x 'Pinova'), J-2004-43 ('Rajka' x 'Rubinola'), J-2002-09-01 ('Gold Milenium' x 6518 Malus floribunda 821), J-2004-22 ('Gold Milenium' x 'Rajka'), J-2004-14 ('Melfree' x 'Topaz'), J-2004-13 ('Melfree' x 'Retina'), J-2002-14-02 (J-79 x 'Szampion'), J-2004-03 ('Free Redstar' x J-79), J-2004-19 ('Gold Milenium' x 'Ariwa') for which the productivity value was evaluated in subsequent seasons 2015-2025. The plant material was produced by the hand-winter grafting of genotypes on M.9 rootstock. Single shoots, about 1.5 m height were than planted (2012) in a medium fertile soil in the orchard. For the experimental trial, trees were planted at the layout of 3.5 m x 1.0 m in the randomized blocks (3 replications, 3 trees per plot). The trees vigour, flower intensity, ripening time, fruit yield and fruit quality (including: weight, skin color, shape, attractiveness and taste) were assessed. The data were compared with the standard cultivars 'Szampion', 'Topaz' and 'Ligolina'. Studied apple clones significantly differ in terms of the evaluated traits. From the pool of analyzed seedlings we selected single clone (J-2004-14), derived from 'Melfree' and 'Topaz' cross, as the most promising, late ripening genotype. Its fruit yield was approximately 5-6 % higher in comparison to 'Szampion' standard cultivar and also surpassed it in fruit taste and attractiveness. Moreover, it is resistant to apple scab and low susceptible to the most economically important pathogens and pests. The new apple cultivar 'Melpaz' was submitted to the Polish National List of Fruit Plant Varieties.

Keywords: *Malus domestica, apple breeding program, apple clones, fruit yield and quality*

Acknowledgments: *The research was carried out in the frame of subsidy of the Ministry of Agriculture and Rural Development special-purpose – Task 3.13: „Developing of an initial apple plant material (Malus domestica Borkh.) with the solid skin color, annually fruiting and resistant to apple scab".*

THE ROLE OF ATP-DEPENDENT 6-PHOSPHOFRUCTOKINASE AND FATTY ACID ELONGASE 3-LIKE (FAE) IN DEFENCE RESPONSE OF APPLE ROOTSTOCKS TO *PHYTOPHTHORA CACTORUM* INFESTATION

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Abstract

In the experiment conducted at the National Institute of Horticultural Research, five apple rootstocks: P 59, P 60, M.9, PJ-173/2012, and PJ-191/2016 were inoculated with Phytophthora *cactorum (agent of ring rot of the apple tree trunk). The RNA samples of the PJ-173/2012 (target) and M.9 (control) rootstocks, collected 48 hours after inoculation, were prepared for tanscriptome sequencing and mapping on the reference apple genome of 'Golden Delicious' (https://www.ncbi.nlm.nih.gov/data-hub/genome/GCF_002114115.1/).*

After sequence reads comparison the differentially expressed genes were classified into functional categories: biological processes (PB, 1,833 GO ontologies), cellular components (CC, 444 GO ontologies), and molecular factors (MF, 904 GO ontologies). For verification studies, RNA samples (from roots) were prepared from the pool of above apple rootstocks collected 48 and 72 hours after P. cactorum inoculation. Not inoculated plants were considered as a controls. Two genes from the biological processes category (GO:0006952, defense response) were selected: LOC114825052 (ATP-dependent 6-phosphofructokinase 2) and LOC103425072 (fatty acid elongase 3-like (FAE)), which seems to be involved in plant defense mechanisms against the pathogen. Phosphofructokinase (PFK) catalyzes the glycolytic pathway and is crucial for cellular energy supply, and plant adaptation to the environment. FAE is involved in the synthesis of very long chain fatty acids (VLCFA), contributing to the formation of lipid barriers such as cuticular waxes. Analysis of expression profiles of both selected genes underlined the significant activation of FAE gene at the early stage of modulation of plant defense mechanism (reconstructing of the lipid cell barrier), while ATP-dependent 6-phosphofructokinase was activated later after fungus infestation, which led to energy mechanism and cell glycolysis modulation.

Our data preliminarily describe of the plan defense process on biotic factors, and demonstrate of the usefulness of putative functional markers for early selection of newly produced pre-breeding materials and monitoring important functional features of apple rootstocks.

Keywords: *apple rootstocks, transcriptome, P. cactorum, gene expression, fatty acid elongase, phosphofructokinase*

Acknowledgments: *The research was carried out in the frame of subsidy of the Ministry of Agriculture and Rural Development special-purpose – Task 3.14: "Production of pre-breeding materials of vegetative rootstocks for apple trees (Malus Mill.), resistant to apple ring rot, tolerant to low temperatures and thornless".*

THE SASKATOON BERRY (*AMELANCHIER ALNIFOLIA* NUTT.) – NEW CROP AND APPLIED BREEDING PROGRAM IN POLAND

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Abstract

Poland has historically a long-standing tradition in the berry crop and fruit production. To enhance the profitability and competitiveness of small fruit cultivation, Polish growers are increasingly exploring new species such as the Saskatoon berry (Amelanchier alnifolia Nutt.). This research has primarily focused on evaluating the adaptability of several Canadian cultivars to local environmental conditions and on developing effective vegetative propagation methods, including in vitro. Field trials included 5 Canadian cultivars ('Honeywood', 'Martin', 'Northline', 'Smoky', 'Thiessen') and 11 advanced clones from our breeding program. Preliminary results indicated that Saskatoon berry could be successfully cultivated in Poland and its fruit production was considerably easier than that of highbush blueberry (Vaccinium corymbosum L.).

The applied breeding program of Saskatoon berry was initiated in 2012 at the National Institute of Horticultural Research in Skierniewice, and financed by the Ministry of Agriculture and Rural Development. The main aims are developing new cultivars well suited to the Polish climate and producing high-quality fruit. The breeding clone (4/3), named 'Amela' has been the first Polish cultivar. In 2022, 'Amela' was entered into the Community Register of Cultivar Protection by the Community Plant Variety Office (CPVO) in Angers, France. 'Amela' showed exceptional productivity, an average fruit yield was 4.3 kg per bush (15,5 tons per hectare), which was 50-93% higher than the Canadian cultivars. The fruits ripen uniformly in early July, are medium-sized (0.7-1.0 g) and having a diameter of 10–12 mm, do not drop from bushes, facilitating both hand and combine harvesting.

In recent years, 3 advanced breeding clones: Clone H, Clone N, Clone 5/6 and several promising breeding seedlings: AM 25/2015, AM 26/2015, AM 17/2013, AM 09/2015, AM 13/2016, AM 42/2015, AM 16/2017, AM 02/2016 have been selected, which will be vegetative propagated to the further research.

Keywords: *new cultivar, 'Amela', CPVO, fruit yield, fruit size, breeding clones*

Acknowledgments: *The research was carried out as part of the targeted subsidy of the Ministry of Agriculture and Rural Development – Task 3.11: "Developing of an initial Saskatoon berry Amelanchier alnifolia plant material for breeding of new cultivars with high quality fruit and tolerance to abiotic stress"*

JAPANESE QUINCE (*CHAENOMELES JAPONICA*): A NEW CULTIVATED SPECIES AND ITS USE IN APPLIED BREEDING IN POLAND

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Abstract

Chaenomeles sp. are known as ornamental shrubs in various regions of the world, such as Europe, Asia, Canada, and the USA, due to their attractive and decorative appearance. Japanese quince (Ch. japonica Thunb./Lindl. ex Spach) is well-known as a fruit species only in the Baltic countries, Belarus, Scandinavia, Ukraine, and recently in Poland. The distinctive, attractive aroma, high organic acid and fiber content, combined with high ascorbic acid (vitamin C) and polyphenol content, make these fruits a valuable raw material for food and the processing industry, due to their nutritional and health-promoting value.

For these reasons, the National Institute of Horticultural Research (InHort) in Skierniewice has begun applied breeding of new Japanese quince cultivars. The main goal is to obtain native genotypes with thornless shoots and good quality fruit with a high content of health-promoting compounds. The breeding program utilizes traditional hybridization methods, which involve crossing of selected parental forms and multi-year phenotypic evaluation of F_1 breeding seedlings, selecting valuable individuals and clones. Traditional hybridization is supported by molecular biology methods, primarily to verify the genetic (DNA) polymorphism of the parental forms and develop molecular markers useful for early mass selection (MAS). Research is also being conducted to analyze the chemical composition of fruit samples of selected genotypes and breeding clones. Additionally, flow cytometry is used to assess the ploidy level/genome size of selected genotypes, the pollen viability of the parental forms used in the breeding programs, and the germination of pollen grains on the stigma. The occurrence and severity of diseases caused by pathogenic fungi, as well as the threat to plants and fruit from pests, are also assessed.

Keywords: *fruit species, nutritional and health value, breeding goals and methods, scientific research*

Acknowledgments: *The research carried out in the frame of subsidy of the Ministry of Agriculture and Rural Development special-purpose Task 3.17: "Development of initial materials of Japanese quince (Chaenomeles japonica* Thunb./Lindl. ex Spach*) with thornless shoots and high quality and content of health-promoting components in the fruit".*

EVALUATION OF CYTOMETRIC, CYTOLOGICAL AND SOME PLANT GROWTH PARAMETERS OF THE TRIPLOID JAPANESE QUINCE GENOTYPE IN RELATION TO DIPLOIDS

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Abstract

Chaenomeles sp. including the Japanese quince (Ch. japonica Thunb./Lindl. ex Spach)) and hybrids are maintained in the breeding collection of the Department of Horticultural Plant Breeding belonging to the National Institute of Horticultural Research (InHort) in Skierniewice, Poland. Selected genotypes were evaluated cytometrically and cytologically. Ploidy levels and genome sizes were assessed. Cytometric analyses of 60 genotypes showed that except for one triploid (3x) plant, all remaining genotypes were diploid (2n = 2x = 34 chromosomes). The genome sizes 2C DNA of the diploid genotypes ranged from 1.30 pg for the cultivar 'Rondo' to 1.70 pg for 'Kalif'. These genome sizes of diploids were comparable to those reported in the literature. For triploid hybrid the genome size was 2.1±0.20 pg. Cytological evaluation revealed that compared to diploids, in triploid genotype, stomata were larger, pollen fertility was significantly lower, and pollen grains were generally larger, but varied in size, indicating aneuploidy of the pollen. The tested diploid genotypes differed significantly in the plant growth vigor, sizes of leaves, flowers, and fruits. The triploid genotype did not differ much from the diploids in these parameters.

Keywords: *Chaenomeles japonica, genome size, ploidy level, pollen germination*

Acknowledgments: *The research carried out in the frame of subsidy of the Ministry of Agriculture and Rural Development special-purpose Task 3.17: "Development of initial materials of Japanese quince (Chaenomeles japonica Thunb./Lindl. ex Spach) with thornless shoots and high quality and content of health-promoting components in the fruit".*

NEW RASPBERRY CULTIVARS AND ADVANCED CLONES BRED AT THE NATIONAL INSTITUTE OF HORTICULTURAL RESEARCH, SKIERNIEWICE, POLAND

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Abstract

Red raspberry breeding at the National Institute of Horticultural Research (InHort) in Skierniewice has been carried out for almost ten years. During this time, many valuable genotypes were bred. Four new cultivars have currently been under the Cultivar Register procedure.

'Skierka' ('Canby' × 'Sokolica') produces fruit twice a season. Fruit harvesting on two-year-old canes begins in the second half of June. On one-year-old canes, the fruits ripen from mid-August until the autumn frosts. Fruits are large, conical in shape, intensely red with a strong glossiness, attractive, very firm and very tasty.

'Ambrozja' ('Glen Ample' × 'Polana') produces fruit twice a season. Fruit harvesting on two-year-old canes begins at the turn of June and July. On one-year-old canes, the fruits ripen from late August until the autumn frosts. Fruits are large, attractive – with a uniform, broadly conical shape and bright red, glossy color, firm and tasty.

'Pola' ('Polana' × 'Sokolica') produces fruit twice a season. Fruit harvesting on two-year-old canes begins in the second half of June. On one-year-old canes, the fruits ripen from early August until the autumn frosts. The fruits are large and attractive – with a uniform, broadly conical shape and an intensely red color with a strong glossiness, firm and tasty.

'Soten' ('Sokolica' × 'Veten') bears fruit on two-year-old canes from mid-June to mid-July. The fruit is very large and attractive – uniformly conical in shape, intensely red in color and glossy, firm and tasty. The canes have few, warty, and unobtrusive thorns.

Additionally, 226 valuable clones have been evaluated in the clone collection. Of these, clones M-2019126-01 and M-2019126-04 ('Tulameen' × 'Przehyba') are the most yielding, producing very large and attractive fruit, while their shoots are completely thornless.

Keywords: *Rubus idaeus L., red raspberry applied breeding, new cultivars, clones, genotypes*

Acknowledgments: *The research carried out in the frame of subsidy of the Ministry of Agriculture and Rural Development special-purpose – Task 3.15: "Developing red raspberry breeding material, for breeding of innovative cultivars with the following features: thorn lessness, double fruit set, increased post-harvest durability of fruit, suitability for mechanical harvesting and increased plant resistance to drought stress".*

‘CELESTYNA’ - A NEW SWEET CHERRY CULTIVAR BRED AT THE NATIONAL INSTITUTE OF HORTICULTURAL RESEARCH IN SKIERNIEWICE

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Abstract

One of the main objectives of the sweet cherry breeding at the National Institute of Horticultural Research (InHort) in Skierniewice is the development of cultivars with early fruit ripening period and the production of large, attractive fruits. As a result of ongoing breeding efforts, two early-ripening cherry clones, C 16-1 and C 16-2, with unknown pedigree, were selected. These clones have been included in cultivar trials, in which the assessment of their production potential is continued. The aim of the present study was to evaluate the growth and fruiting of trees of the new cherry clones.

The experiment was established in autumn 2017 at the Experimental Orchard in Dąbrowice (central Poland), belonging to the Inhort in Skierniewice. Trees of the tested clones and standard cultivars were grafted on the vegetative rootstock ‘Gisela 5’. The cultivar ‘Burlat’ served as the control in the experiment.

Trees of both tested clones, C 16-1 and C 16-2, presented weaker vegetative growth compared to the control cultivar ‘Burlat’. However, the trees of the new clones produced significantly higher yields than the control cultivar, and due to their lower vigor, they also demonstrated a markedly higher cropping efficiency. The fruits of both clones ripened at a similar time, 4–7 days earlier than the fruits of ‘Burlat’, and they were slightly larger. Among the tested clones, trees of clone C 16-2 showed higher yields and produced somewhat larger fruits compared to clone C 16-1. Therefore, clone C 16-2, due to its early fruit ripening, high yield potential, and production of large fruits, was submitted in 2025 to the Polish Register of Fruit Plant Varieties under the name ‘Celestyna’. This new cultivar is expected to be used in future breeding programs aimed at developing of early-ripening sweet cherry cultivars.

Keywords: *Prunus avium*, sweet cherry breeding, new cultivar, yield

Acknowledgments: *The research was supported by the Ministry of Agriculture and Rural Development special-purpose – Task 3.10: „Development of an initial sweet cherry (Prunus avium L.) plant material producing high-quality and crack-tolerant dessert fruits using embryo rescue technique”.*

GENETIC MAPPING OF THE LOCUS ASSOCIATED WITH MALE STERILITY IN SWEET PEPPER (CAPSICUM ANNUUM L.)

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Abstract

Commercial production of hybrid seeds typically relies either on manual pollination or on genetic mechanisms that facilitate controlled crossing of parental lines. Among these, nuclear male sterility represents a cost-effective strategy for hybrid seed production, ensuring high genetic purity of F_1 seed. In sweet pepper (Capsicum annuum L.), the ms8 nuclear male sterility locus has been genetically mapped to chromosome P4; however, this gene has not yet been identified nor cloned, and the molecular mechanism underlying male sterility remains unknown.

The aim of this study was to validate molecular markers developed from sequence polymorphisms identified by bulked segregant analysis coupled with whole-genome resequencing (BSA-seq) to refine the genomic region harboring the ms8 locus.

Based on sequence variants identified within the genomic region of ms8 locus, a set of InDel and CAPS/dCAPS markers was developed. The markers were validated using the parental lines, F_1 plants, and individuals from an $F_{2:3}$ mapping population derived from a cross between the male-sterile ms8 line and the fertile H3 line. PCR amplification, restriction enzyme digestion, and agarose electrophoresis were performed to evaluate marker polymorphism, verify marker–phenotype associations, and confirm expected segregation patterns.

The developed markers reliably distinguished fertile, heterozygous, and male-sterile genotypes, confirming the position of the ms8 locus on chromosome P4. Genotyping of recombinant individuals enabled further narrowing of the candidate genomic interval and the identification of markers tightly linked to the ms8 locus. These markers provide support for further fine mapping of the ms8 locus, facilitating candidate gene identification, cloning, and functional characterization.

Keywords: *Capsicum annuum, male sterility, molecular markers, InDel, CAPS, genetic mapping*

Acknowledgments: *This research was supported by the National Science Centre, Poland (NCN), MINIATURA 8, project No. 2024/08/X/NZ9/01302. The conference participation was funded by the PROM Programme – International Scholarship Exchange of PhD Candidates and Academic Staff, implemented by the Polish National Agency for Academic Exchange (NAWA).*

GREEN ZINC OXIDE NANOPARTICLES AS SEED NANOPRIMING AGENTS ENHANCED GERMINATION AND EARLY SEEDLING PERFORMANCE OF *CAPSICUM ANNUUM* L. (CHILI)

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Abstract

The findings demonstrated that zinc oxide nanoparticles (ZnONPs), particularly at a concentration of 90 ppm, significantly enhanced seed performance, as evidenced by a higher germination rate index, increased seedling fresh weight, and greater seedling length. Seed priming with ZnONPs further stimulated key metabolic and biochemical processes, resulting in elevated levels of total soluble sugars, total phenolic compounds, and total amylase activity. These indicating improved reserve mobilization and strengthened antioxidant capacity during early growth stages. Moreover, both ZnONPs and silver nanoparticles (AgNPs) markedly reduced malondialdehyde (MDA) content, an indicator of lipid peroxidation and oxidative damage. This reduction suggests that nanoparticle treatments effectively play a crucial role in mitigating oxidative stress, thereby protecting cellular integrity during germination and seedling establishment. This protective effect id essential for improving plant resilience under stress conditions. Collectively, these results highlight the potential of nanoparticle-mediated seed priming as an innovative and efficient strategy to enhance seed vigor, accelerate early growth, and improve stress tolerance. The study provides valuable insights into the physiological and biochemical mechanisms underlying nanoparticle-induced seed enhancement, offering promising implications for sustainable crop production and advanced nanobiotechnology applications in agriculture.

Keywords: *nanopriming, nanoparticles, seed germination, Capsicum annuum*

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TECHNOLOGICAL ELEMENTS OF CARROT CULTIVATION IN RAISED BEDS

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Abstract

Sustainability is a central concept in agriculture and horticulture, aiming to satisfy global market demands while preserving environmental quality for future generations. Carrot (Daucus carota subsp. sativus) is a major taproot vegetable crop with high nutritional value, recognized health benefits, and strong economic importance. The edible roots are rich in bioactive compounds essential to the human diet, highlighting the need to integrate crop technology with genetic diversity within sustainable plant breeding programs.

This study aims to develop and evaluate a sustainable growth technology for carrots cultivated in raised beds, with emphasis on root yield and size uniformity. Five carrot hybrids representing different root colors are investigated: orange (Carnaval), yellow (Jeune de Doubs), purple (Purple Sun H), and two red cultivars (Koral and Chantenay à cœur rouge 2). Raised beds are constructed using wooden frames and agrotextile ground cover and filled with a substrate composed of peat, soil, and sand (40:40:20). Crop management includes drip irrigation, the application of both conventional and organic fertilizers, and targeted plant protection treatments against aphids and powdery mildew.

The raised-bed system provides favorable conditions for carrot development, contributing to improved root quality and yield performance, and supports its suitability as a sustainable cultivation technology for diversified carrot breeding and production systems.

Keywords: *carrot crop, raised beds, crop technology, plant breeding*

NANO-MATERIAL-MODIFIED SHADING ALTERS BASIL GROWTH AND RHIZOSPHERE-RELATED SOIL INDICATORS

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Abstract

In horticultural production systems, plant performance is strongly influenced by the radiation and thermal conditions experienced by the canopy. Periods of high irradiance and elevated temperature can disturb leaf energy balance, increase transpiration demand, and constrain biomass accumulation. Shading technologies are therefore widely used to mitigate radiation and heat stress by modifying canopy microclimate, although conventional shading may also reduce photosynthetically active radiation and affect growth dynamics. Recent technological developments have introduced nano-material-modified shading systems designed to regulate the optical properties and thermal behavior of covering surfaces while maintaining comparable light transmission. The present study examined how the MANTI nano-material-modified shading system, developed and distributed by Műszerautomatika Ltd., influences growth responses in basil (Ocimum basilicum L.) and how these responses relate to selected indicators of soil processes in the root zone. The experiment was conducted at the experimental horticultural station of the Hungarian University of Agriculture and Life Sciences in Budapest. Basil plants were grown under two canopy environments: an uncovered control and a nano-modified shading treatment. Growth parameters, root traits, and selected soil indicators were evaluated. The results showed that canopy microclimate modification altered vegetative development and biomass allocation patterns. Plants grown under the modified canopy environment developed higher leaf numbers but lower shoot biomass, while root traits also showed treatment-specific differences. These patterns suggest that microclimate regulation can influence plant growth strategy and may affect rhizosphere functioning. Integrating canopy-level plant responses with soil biological indicators may therefore improve the evaluation of microclimate management technologies in horticultural production systems.

Keywords: *basil, canopy microclimate, nano-material-modified shading, MANTI, biomass allocation, root traits, rhizosphere, horticultural production*

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ESSENTIAL OIL CONTENT AND ANTIOXIDANT ACTIVITY OF *ROSA* × *CENTIFOLIA* L. CULTIVATED IN A WARM AGROCLIMATIC REGION

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Abstract

Rosa × centifolia L. is an important source of rare rose essential oil, whose natural concentration in flowers is low and strongly influenced by agroclimatic conditions. The antioxidant activity of this taxon is shaped by a diverse spectrum of secondary metabolites, including flavonoids, phenolic acids, tannins, proanthocyanidins, and minor carotenoids. This study examined the qualitative profile of the herbal drug Rosae flos, focusing on essential oil yield and antioxidant capacity across different flowering phenophases. A clear relationship was confirmed between flower ontogeny and the accumulation of bioactive compounds: essential oil content peaked in phenophase F2 (0.04 ml·100 g^{-1}), whereas total phenolics reached their maximum in phenophase F3, particularly in dark-coloured flowers. Antioxidant activity (DPPH) remained stable (1.32–1.40 mg TE·g^{-1} DW), indicating a consistently high biological value throughout the flowering period. As both the quantity and quality of essential oil and antioxidant compounds vary with genotype and environmental conditions, evaluation in warm agroclimatic regions is essential. The results identify phenophase F2 as optimal for essential oil distillation and phenophase F3 for obtaining antioxidant-rich extracts, providing valuable guidance for breeding and cultivation strategies of Rosa × centifolia L. in Central European growing conditions.

Keywords: *antioxidant activity, DPPH assay, essential oil content, phenological stages, Rosa × centifolia L., secondary metabolites*

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IN VITRO PROPAGATION OF *ROSA* × *CENTIFOLIA* L.

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Abstract

The rose is among the most important commercial ornamental crops, yet its traditional vegetative propagation through cuttings and nodal buds is constrained by plant health, seasonality, and slow growth. In vitro propagation is an efficient alternative that enables the rapid production of large numbers of healthy plants, with success determined by genotype, the physiological condition of the plant material, and an appropriately selected sterilisation procedure. The in vitro propagation methodology for Rosa × centifolia L. highlights differences in sterilisation protocols and culture media. Sterilisation of explants was identified as a key limiting factor in establishing aseptic cultures. Initial attempts using the sterilisation protocol revealed high levels of contamination, indicating the presence of endophytes that cannot be eliminated by surface disinfection alone. Testing of three sterilisation protocols confirmed that sodium hypochlorite alone is unable to penetrate deeper tissue layers. The highest effectiveness was achieved with the second protocol, which combined mechanical cleaning, detergent pre-treatment, and sequential exposure to ethanol, Ajatin, NaClO, and TWEEN 20. Nevertheless, internal microflora could not be completely removed, leading to delayed contamination in some cultures. Substrate K1 (kinetin + 6-BA) showed the highest proportion of uncontaminated explants (77.8%), whereas substrate K0, lacking growth regulators, achieved the lowest success rate (10%). These results suggest a synergistic effect of cytokinins on tissue vitality and their tolerance to sterilisation-induced stress. The optimised multicomponent sterilisation protocol substantially reduced contamination levels; however, endogenous microflora remained the dominant limiting factor. The stability of aseptic cultures was highest when MS medium supplemented with kinetin and 6-BA was used, supporting its applicability in rose in vitro propagation. Overall, the results confirm that the success of in vitro rose cultivation is determined by the interaction between the sterilisation procedure and the composition of the culture medium.

Keywords: *culture medium, cytokinin supplementation, endophytic contamination, in vitro propagation, sterilisation protocols, Rosa × centifolia*

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TECHNOLOGICAL METHODS OF ESSENTIAL OIL EXTRACTION FROM *ROSA CENTIFOLIA* L.

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Abstract

Since the European Pharmacopoeia does not establish specific requirements for essential oil determination directly in the flowers of Rosa × centifolia L., the general pharmacopoeial method for essential oils in herbal drugs (Ph. Eur., chapter 2.8.12) was applied in this study. The aim of the research was to investigate and evaluate technological methods of essential oil extraction from Rosa centifolia and their impact on the quality and yield of the obtained essential oil, in order to identify the optimal extraction method ensuring maximum essential oil quality for commercial production and application in the cosmetic and pharmaceutical industries. Flowers were disintegrated in a laboratory mill immediately prior to processing to ensure optimal release of volatile compounds from the essential oil glands. Hydrodistillation was performed in a round-bottom flask with distilled water and boiling chips, using xylene as a collecting solvent to prevent adhesive losses on the glass walls. The distillation rate was maintained constant via a heating mantle, and the essential oil content was calculated as the difference between the total measured volume and the blank xylene volume, expressed per fresh weight of the drug. Samples were collected at three developmental stages of the flower (F1, F2, F3). The essential oil content ranged from 0.02 to 0.04 ml·100 g^{-1}, showing considerable variability depending on the developmental stage. The highest essential oil content was recorded in stage F2 (up to 0.04 ml·100 g^{-1}), followed by F1, while the lowest content was found in stage F3 (0.02 ml·100 g^{-1}). The full bloom period (F2) is characterized by intensive biosynthesis of monoterpenes, aromatic alcohols, and esters, the principal carriers of the characteristic rose aroma, whereas the decline observed in stage F3 may be attributed to reduced biosynthetic activity and increased volatilization of aromatic compounds. These results indicate that the developmental stage of the flower is a decisive factor influencing essential oil content in Rosa × centifolia L. petals, with stage F2 representing the most suitable harvest time for obtaining high-quality raw material for aromatic, cosmetic, and pharmaceutical applications.

Keywords: *Rosa centifolia, essential oil, hydrodistillation, flower ontogenesis, extraction method*

Acknowledgments: *This research was funded by VEGA 1/0387/25 "Environmental screening of plant resources in the soil-ecological units of Slovakia for optimal use of the landscape" and KEGA 056UK-4/2025 "Internationalisation of education and innovation in theoretical and practical teaching within the Pharmacy study programme".*

INVOLVEMENT OF PHYTOCHROME SIGNALLING IN PIPECOLIC ACID-MEDIATED DEFENCE RESPONSES OF TOMATO PLANTS

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Abstract

Pipecolic acid (Pip) is a central regulator of local and systemic plant defence responses against microbial pathogens. Besides light intensity, light quality also strongly influences plant immunity. In this study, the role of phytochromes in Pip-induced defence signalling was investigated using different tomato phy mutants. Twenty-four hours after Pip treatment, wild-type (WT) plants showed significantly increased superoxide and H_2O_2 accumulation accompanied by enhanced antioxidant enzyme activity. In phya mutants, H_2O_2 levels and catalase activity increased markedly, whereas superoxide dismutase induction was less pronounced. Even weaker responses were detected in phyb1b2 mutants, supporting the involvement of phytochromes in Pip-induced signalling. Nitric oxide levels remained unchanged in all genotypes. Pip induced both local and systemic increases in ascorbate (ASA) and glutathione (GSH) levels. Although ASA levels were lower in the phy mutants, Pip still triggered a local increase in ASA in these plants. In contrast, GSH levels remained unchanged in the phy mutants. The local and systemic expression of SlPR1 was induced by Pip in WT plants, and a similar response was observed in phya mutants, while the systemic induction was absent in phyb1b2 plants. The expression of SlDEF9 and SlERF1 also increased locally and systemically in WT plants, but weaker induction was detected in both phya and phyb1b2 mutants. Pip treatment alleviated both local and systemic Botrytis cinerea and Pseudomonas syringae infections in WT plants. Although similar tendencies were observed in phya mutants, the protective effect was weaker, while phyb1b2 mutants were considerably more susceptible and showed impaired development of both local and systemic resistance.

Keywords: *phytochrome, pipecolic acid, reactive oxygen species, red light, tomato*

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ETHYLENE SIGNALING MEDIATES A-PINENE-INDUCED DEFENCE RESPONSES IN TOMATO PLANTS

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Abstract

Volatile organic compounds (VOCs) are essential components of plant defence against pathogens. Their physical characteristics enable not only communication among different plant organs but also rapid signal transmission between neighbouring plants. Although α-pinene is known to influence multiple hormonal signalling pathways and trigger systemic acquired resistance, its interaction with ethylene (ET) remains poorly understood.

In this study, wild-type (WT) and Never ripe (Nr) tomato plants, which have impaired ET perception, were treated with α-pinene. Defence-related physiological and molecular responses were monitored over 24–72 hours. α-Pinene significantly increased ET production and enhanced reactive oxygen species (ROS) accumulation in both WT and Nr leaves. In contrast, nitric oxide (NO) levels increased significantly only in WT plants. Superoxide dismutase activity increased significantly in WT plants but not in Nr leaves. Catalase and ascorbate peroxidase activities remained unchanged. Levels of non-enzymatic antioxidants decreased during the first two days. However, ascorbate levels recovered in WT plants after 72 hours, while reduced glutathione levels remained stable in Nr plants. Analysis of hormonal marker gene expression indicated a pronounced salicylic acid-associated response in WT plants, whereas Nr plants predominantly showed jasmonic acid-related gene expression. Pathogen assays demonstrated that α-pinene pre-treatment enhanced WT resistance to Pseudomonas syringae and reduced lesion size caused by Botrytis cinerea, but only in Nr leaves. Overall, these findings suggest that ET fine-tunes α-pinene-induced priming by regulating ROS metabolism and hormonal signalling, thereby modulating defence effectiveness against different pathogens.

Keywords: *α-pinene, ethylene signalling, defence priming, tomato, plant-pathogen interactions*

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EFFECT OF LONG-TERM RED LIGHT INTER-LIGHTING ON CARBOHYDRATE METABOLISM AND MORPHOLOGICAL TRAITS OF TOMATO PLANTS

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Abstract

Tomato (Solanum lycopersicum L.) is one of the most widely cultivated and most important greenhouse crops worldwide. In order to increase production efficiency, numerous studies have examined environmental factors whose modification can enhance yield and fruit quality in a cost-effective and environmentally friendly way. Among these factors, light has a particularly important effect. The role of light accompanies plants throughout their entire life cycle, from germination through individual development and reproduction to death, not least including defense against pathogens. Previous studies have demonstrated that illumination applied at different times of the day, with varying wavelengths and durations, can have a significant impact on plant physiological processes. The red light used in our research has been proven to improve photosynthetic efficiency, increase biomass production, enhance defense responses against biotic stress, and influence morphology. During our experiment, a so-called "inter-lighting" system was applied, in which supplemental lighting is positioned between the leaf layers. This method enables a more uniform distribution of light and more efficient utilization at different canopy levels. In our study, two tomato genotypes were compared: Ailsa Craig, which was used as the wild type, and Never ripe, which carries a mutation in an ethylene receptor. The aim of our research was to explore how red inter-lighting applied at different times of the day and for varying durations induces ethylene-dependent changes in the photosynthetic activity, CO_2 assimilation, and carbohydrate metabolism of leaves of different ages, and how these changes affect plant morphological traits, primarily the density of type VI glandular trichomes on the leaves. This change is likely to influence the profile of volatile organic compounds (VOCs).

Keywords: *tomato, red light, inter-lighting, morphology, glandular trichome*

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THE ROLE OF ROOT-TO-SHOOT LENGTH RATIO AND GLUTATHIONE S-TRANSFERASES IN DROUGHT-TOLERANT HYBRID WHEAT UNDER OSMOTIC STRESS

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Abstract

Climate change-induced drought represents a major challenge for wheat production, particularly during early developmental stages. We investigated the physiological and molecular mechanisms underlying drought tolerance in the hybrid wheat cultivar SU Hycardi compared with the drought-sensitive cultivar Lindbergh, with special emphasis on root architecture, osmotic adaptation, photosynthetic performance, and glutathione S-transferase (GST)-related detoxification.

The hybrid cultivar developed a longer and more robust root system, accompanied by a shoot-to-root ratio favoring root biomass already at the seedling stage. Under PEG-induced osmotic stress, leaf water potential decreased in both genotypes; however, in SU Hycardi this reduction was limited to the older leaves, indicating more efficient water retention. Photosynthetic measurements showed significant stress-induced declines in Lindberg, particularly in the performance index (Pi_Abs) and electron transport rate (ETo/RC), whereas SU Hycardi maintained relatively stable photosynthetic activity. Higher GST activity was detected in the roots of the hybrid cultivar even under control conditions, suggesting an enhanced detoxification capacity. GST gene expression patterns are different in the two genotypes.

The results indicate that the superior drought tolerance of the SU Hycardi cultivar is associated with a complex adaptive response involving enhanced root development, improved water management, stable photosynthetic performance, osmotic adaptation, and efficient detoxification mechanisms.

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EFFECT OF RAPESEED GENOTYPE ON SECONDARY METABOLITE CONTENT UNDER STRESS CONDITIONS

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Abstract

Oilseed rape (Brassica napus L.) is an important oil crop with wide applications in agriculture, the food industry, and pharmaceuticals. The aim of our study was to investigate the effects of salt stress, induced by different NaCl concentrations, on germination, physiological parameters, and the accumulation of selected metabolites in six various genotypes of oilseed rape.

The experiments showed that salt stress primarily affects germination dynamics and subsequent plant growth, with higher NaCl concentrations (100 mM) leading to growth inhibition and reduced biomass. It was also demonstrated that plants respond to stress by activating defense mechanisms involving the accumulation of osmotically active compounds.

The content of proline and soluble sugars significantly increased under mild NaCl concentrations (50 mM), while increasing salinity led to altered accumulation of secondary metabolites (polyphenols and flavonoids), with an overall increase in their content. Salt stress also negatively affected the content of photosynthetic pigments, which was associated with reduced photosynthetic activity.

Overall, the results suggest that B. napus L. possesses several adaptive mechanisms that enable partial tolerance to salt stress, with osmotic and antioxidant regulation playing a key role.

Keywords: *Oilseed rape, salt stress, secondary metabolites, flavonoids, polyphenols, proline*

Acknowledgments: *This research was supported by APVV-24-0180 project and KEGA 012UCM-4/2025 project.*

WHITE MUSTARD: ENERGY BALANCE AT DIFFERENT NITROGEN MANAGEMENT STRATEGIES

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Abstract

The article presents the results of a three-year study (2020-2022) aimed at determining the effect of N fertilization (0, 40, 80, 120, and 160 kg ha^{-1}) on biomass yields (seeds alone or seeds and straw) and the energy balance of white mustard (Sinapis alba L.) produced in a large-area farm in Poland. The demand for energy in the production technology without N fertilization ranged from 6.9 (seeds) to 7.4 GJ ha^{-1} (seeds and straw). Nitrogen increased energy inputs by 3.1- 3.4 GJ ha^{-1} per every 40 kg N ha^{-1}. Seed and straw yields were 1.24-1.53 and 1.27-2.09 Mg ha^{-1} DM, respectively. Seed and straw yields peaked in response to the N rates of 160 and 120 kg ha^{-1}, respectively. The energy output of seeds and total biomass was lowest in the production technology without N fertilization (28.9 and 55.8 GJ ha^{-1}, respectively). Nitrogen application increased the energy output of seeds and total biomass by 37.4% and 28.7%, respectively. The energy gain from total biomass was 2.5 times higher than the energy gain from seeds (53.0 vs. 20.8 GJ ha^{-1}). Nitrogen fertilization decreased the energy gain from seeds and increased the energy gain from total biomass. The energy efficiency ratio of the white mustard production technology was determined at 2.58–3.17 (seeds) and 3.70–7.55 (total biomass). The energy efficiency ratio of seeds and total biomass was highest in treatments without N fertilization. In treatments supplied with N, this parameter decreased by 18.3–26.0% (40 kg N ha^{-1}) and 35.9–51.6% (80–160 kg N ha^{-1}).

Keywords: *Sinapis alba L., biomass yield, fertilization, energy inputs, energy output, energy gain, energy efficiency ratio*

Acknowledgments: *The results presented in this paper were obtained as part of a comprehensive study financed by the University of Warmia and Mazury in Olsztyn (grant No. 30.610.013–110). The study was funded by the Minister of Science under the Regional Initiative of Excellence Program.*

EFFECT OF FOLIAR APPLICATION OF A MULTI-COMPONENT MICRONUTRIENT FERTILIZER ENRICHED WITH KAEMPFEROL ON THE PHYSIOLOGICAL PROPERTIES OF JERUSALEM ARTICHOKE (*HELIANTHUS TUBEROSUS* L.)

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Abstract

Jerusalem artichoke (Helianthus tuberosus L.) is a multipurpose crop with potential for food, feed and bioenergy production, particularly on marginal soils. The study evaluated whether foliar application of a multi-component micronutrient fertilizer enriched with kaempferol improves the physiological status of the cultivar Albik. A pot experiment was conducted under controlled growth-chamber conditions. Plants were treated 15 days after emergence with a fertilizer containing Cu, Mn and Zn, applied at 4 mL L^{-1} and supplemented with kaempferol at 1, 2 or 3 g L^{-1}. The control received deionized water. Physiological measurements were performed 1, 7 and 14 days after application and included gas exchange, relative chlorophyll content and chlorophyll fluorescence. The treatments enhanced photosynthetic activity compared with the control, with the strongest increase in net photosynthesis observed after the highest kaempferol dose. Transpiration and stomatal conductance also increased, although the transpirational response was greatest at the intermediate dose. Relative chlorophyll content rose markedly after foliar fertilization, particularly at the two higher kaempferol doses. Chlorophyll fluorescence parameters indicated improved photochemical efficiency of photosystem II and higher photosynthetic performance, without evidence of treatment-related injury. The response was generally dose- and time-dependent, with the most pronounced effects recorded 14 days after application. The findings indicate that a kaempferol-enriched micronutrient foliar fertilizer can support the physiological performance of Jerusalem artichoke by improving gas exchange, chlorophyll accumulation and photochemical efficiency. Further research should verify these responses under field conditions and assess their implications for biomass yield and quality.

Keywords: *Jerusalem artichoke, Helianthus tuberosus, foliar fertilization, kaempferol, micronutrients, photosynthesis, chlorophyll fluorescence*

BROMUS INERMIS LEYSS. (SMOOTH BROME, AWNLESS BROMEGRASS), A VALUABLE FODDER SPECIES WITH A MULTIFUNCTIONAL CHARACTER, IN THE CURRENT EUROPEAN CLIMATE CONTEXT

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Abstract

Climate change over the last 15 years in Europe has marked a period of accelerated warming, with the continent being considered the fastest warming in the world. Temperatures increased by more than 2 °C compared to pre-industrial levels, exceeding the global average pace. Summers became hotter, with an average daily temperature record of 22,63 °C recorded in July 2024. While the south has dried up, other areas have experienced torrential rains and massive flooding, a „new normality" caused by the warmer atmosphere that retains more moisture. Under these conditions, established perennial fodder grass species cannot easily adapt and offer low yields and poor feed quality. Bromus inermis Leyss. *is a species of perennial grass, stoloniferous, with erect stems up to 150 cm high and a very high vivacity (over 10 years in pure culture), spontane or cultivated in the steppe and silvoatepe areas. It is a species with minimal requirements to vegetation factors, valuing degraded land, poorly fertile or subject to erosion, where other species do not give results. Research and Development Station for Meadows, Vaslui (RDSM Vaslui) has in its breeding program the Bromus inermis* Leyss. *species, in which it owns 490 genetic resources kept in the field and in the breeding laboratory in the form of seed and 6 varieties created: Doina, Olga, Mihaela, Iulia Safir, Maia Safir and Dovas. Annually, more than 5 tons of seed material are produced for marketing. It can be used for obtaining feed, for setting up temporary meadows, for over-seeding degraded, eroded permanent grasslands, for greening polluted areas, for fast fixation of agroterraces, terraces, dams, banks of irrigation channels, for fast and long-term fixation of areas of modelled land, as a result of road or highway construction, in aquaculture in the rapid grassing and creation of optimal conditions in fish breeding basins.*

Keywords: *feed production, alternative uses, multifunctionality, seed stock*

Acknowledgments: *All breeding research within the RDSM Vaslui was funded by Ministry of Agriculture and Rural Development - Romania through the Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu - Şişeşti" - Bucharest.*

INTEGRATING ADAPTIVE STRATEGIES INTO CROP ROTATION FOR SUSTAINABLE AGRICULTURE

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Abstract

Climate change, together with rising temperatures, water scarcity, and an increasing frequency of extreme weather events, poses a significant threat to global food security, with projected yield declines of up to 24% for major cereal crops by 2050. Crop rotation, combined with effective biomass management, represents a cornerstone of sustainable agriculture, enhancing soil health and improving nutrient management, thereby helping farmers adapt to these growing challenges. The aim of this study was to evaluate the impact of cultivation interventions on sustainability factors within diversified crop rotations, using crop yield and yield components as key indicators of productivity and resilience under variable climatic conditions. A long-term field experiment was conducted at Dolná Malanta near Nitra, western Slovakia (2005–2021), in a four-plot crop rotation comprising milk thistle (Silybum marianum (L.) Gaertn.) with white mustard as a catch crop, maize (Zea mays L.), field pea (Pisum sativum L.), and durum wheat (Triticum durum Desf.) with white mustard as a catch crop. The above-ground biomass of catch and forecrop residues was used as green manure. Treatments differed in organic matter management (ploughing-in versus removal of forecrop residues), the use of a catch crop, and fertilisation (with or without industrial fertilisers). Data were evaluated using two-factor ANOVA, LSD testing, and correlation analysis of yield-forming components. The results showed that treatments combining industrial fertilisation with the incorporation of above-ground biomass from the preceding crop achieved significantly higher and more stable yields across years than unfertilized treatments, in both maize and common pea. The average maize grain yield ranged from 4.44 t ha^{-1} in 2017 to 5.07–5.47 t ha^{-1} in 2018–2019, while pea grain yield ranged from 1,9–2,4 t ha^{-1} and was significantly higher under the combined fertilisation treatment (RF) than under the control, biomass-only, or fertiliser-only treatments. Correlation analysis confirmed close relationships between yield-forming components (pods per plant, pods per m², seeds per pod) and final grain yield, indicating opportunities to influence yield through targeted management of these components. The findings confirm that combining effective fertilisation with organic matter management within diversified crop rotations is essential for maintaining stable and resilient crop production under increasing climatic pressure, supporting the broader goal of sustainable intensification of agroecosystems.

Keywords: *crop rotation, climate change adaptation, biomass management, fertilisation, maize, peas, sustainable agriculture, yield stability*

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EVALUATION OF ARTIFICIAL INOCULATION METHODS OF *SCLEROTINIA SCLEROTIORUM* IN WINTER OILSEED RAPE UNDER FIELD CONDITIONS

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Abstract

Artificial inoculation is essential for reliable evaluation of Sclerotinia stem rot in oilseed rape caused by Sclerotinia sclerotiorum, due to the variability of natural infection. However, the effectiveness and reproducibility of different inoculation methods in the field remain insufficiently standardized. This study aimed to compare multiple artificial inoculation techniques in winter oilseed rape under field conditions, assessing their reliability, dose response and suitability for field use. Field experiments were conducted in 2023 and 2025 at two locations, using different inoculation methods and hybrids. The methods included a mycelium suspension, colonized millet, dried colonized millet and powdered sclerotia. Disease development was assessed using incidence, severity and a modified disease severity index (DSI). Significant differences were observed between the inoculation methods. Colonized millet resulted in the most consistent and reliable disease levels across locations and years. The effectiveness of mycelium suspension and sclerotia-based methods was limited under field conditions. A clear dose-dependent increase in disease severity was observed for colonized millet in 2025, demonstrating the potential to regulate infection pressure. Differences between hybrids were observed, but these were not statistically significant. The results suggest, that inoculum type and physiological state are key factors in determining infection success. Colonized millet is a robust and practical inoculation method for field experiments, whereas other approaches may be less suitable for open-field conditions. These findings contribute to the development of standardized, reproducible inoculation protocols for S. sclerotiorum research in oilseed rape.

Keywords: *Sclerotinia sclerotiorum, winter oilseed rape, artificial inoculation, inoculum, field experiment*

SUSCEPTIBILITY OF DURUM WHEAT TO INFECTIONS CAUSED BY *FUSARIUM GRAMINEARUM, BLUMERIA GRAMINIS* F.SP. TRITICI AND *ZYMOSEPTORIA TRITICI* IN POLAND

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Abstract

Great challenge in the durum wheat production is its high susceptibility to fungal pathogens. The aim of this study was to identify spring cultivars of durum wheat that are less susceptible to Fusarium graminearum infections and the accumulation of deoxynivalenol (DON) in grain, as well as infections caused by Blumeria graminis f.sp. tritici and Zymoseptoria tritici. Two experiments were established in different locations in Poland. In 2018-2019, symptoms of Fusarium head blight were noted sporadically, whereas in 2020, the disease was endemic in both experimental sites. In 2020, symptoms of Fusarium leaf blight were observed in southern Poland, and symptoms of STB were noted in the northern part of the country. The severity of powdery mildew was low, and disease symptoms were observed mainly on lower leaves in all cultivars. Fhb2, Stb1, Stb2, Stb3, Pm36, and Pm41 alleles were identified in the tested cultivars. Cultivar IS Duragold grown in a greenhouse was least susceptible to primary infection by F. graminearum and the growth of fungal hyphae on the rachis. After inoculation, DON was accumulated in spikelets in all cultivars, in particular Duramant (1582 mcg/kg) and Durasol (1455 mcg/kg). Most suitable for cultivation were cultivars IS Duragold and IS Duranegra.

Keywords: *Triticum durum*, mycotoxins, fungal diseases

Acknowledgments: *This research is the result of a long-term study conducted at the Department of Genetics, Plant Breeding and Bioresource Engineering and Department of Entomology, Phytopathology and Molecular Diagnostics Faculty of Agriculture and Forestry of the University of Warmia and Mazury in Olsztyn (research topics 30.610.007-110 and 30.610.011-110). The study was funded by the Minister of Science under the "Regional Initiative of Excellence" Program.*

PEST AND DISEASE PRESSURE IN WINTER OILSEED RAPE AS AN INDICATOR OF AGROECOSYSTEM FUNCTIONING

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Abstract

Agricultural biodiversity is essential for maintaining agroecosystem stability and ensuring ecosystem services such as natural pest and disease regulation. Winter oilseed rape (Brassica napus L.) is a key oilseed crop in Northern Europe; however, its productivity is strongly affected by biotic stress factors. This study aimed to assess abundance and severity in winter oilseed rape fields and to assess their suitability as indicators.

Field surveys were conducted in three farming systems located in different regions of Lithuania. Pest abundance was expressed as the mean number of individuals per plant, while disease severity was evaluated as the percentage of damaged plant tissue using standardized assessment methods. The highest pest pressure was recorded for pollen beetles (Meligethes aeneus), reaching up to 8 individuals per plant, and flea beetles (Phyllotreta spp.), with an average of 4–6 individuals per plant. Weevil species (Ceutorhynchus spp.) abundance ranged from 0 to 6 individuals per plant, depending on the site. Disease severity varied among locations: black spot affected 8–15% of plant tissue, phoma stem canker 5–10%, and white rot caused the most severe damage, reaching up to 30%.

The results demonstrate pronounced spatial variability in pest and disease pressure, reflecting differences in agroecological conditions and crop management practices. Pest and disease dynamics can therefore serve as reliable indicators of agroecosystem functioning, supporting sustainable crop protection and ecosystem service enhancement.

Keywords: *agricultural biodiversity, agroecosystem health, winter oilseed rape, pest and disease dynamics, ecosystem services*

THE EFFECT OF ROS AND FUNGICIDES USED IN POTATO CULTIVATION ON DISEASE INFECTION, PLANT PHYSIOLOGY, TUBER QUALITY, AND YIELD

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Abstract

The integration of alternative oxidative treatments with conventional disease control could support more sustainable potato cultivation, but their agronomic value must be evaluated against standard fungicide protection. This study synthesizes field results on the effects of reactive oxygen species (ROS), represented by ozone fumigation (O_3) foliar application of hydrogen peroxide (H_2O_2), and fungicides used in potato cultivation on late blight infection, leaf physiological status, tuber quality, and yield. Field experiments were conducted in 2017 and 2018 in Łańcut, Poland, under natural Phytophthora infestans pressure. The main experiment compared an untreated control, O_3, H_2O_2, and fungicide protection using a 1-9 late blight rating scale, SPAD readings, and total tuber yield. Tuber-quality interpretation was limited to non-mineral chemical descriptors: starch content, ABTS, DPPH, total polyphenolic compounds, and CUPRAC. Fungicide protection most effectively maintained plant health, especially in 2018, when the final late blight rating remained higher under fungicide treatment (7.30) than in the control (4.15), H_2O_2 (3.75), or O_3 (3.80) variants. The adjusted mean yield was also highest under fungicide protection (5.44 kg m^{-2}), whereas the control, H_2O_2, and O_3 yielded 4.51, 4.44, and 4.07 kg m^{-2}, respectively. SPAD responses varied by year and treatment, indicating that leaf greenness and physiological status reflected both protection strategy and seasonal conditions. Starch content was comparatively stable across repeated ozonation. Overall, fungicide protection remained the most effective treatment for limiting late blight and sustaining yield, whereas O_3 and H_2O_2 acted as selective modifiers of plant and tuber traits rather than direct substitutes for standard chemical protection.

Keywords: *potato late blight, reactive oxygen species, ozone fumigation, hydrogen peroxide, fungicide protection, SPAD index, tuber yield, starch content*

SELECTED BIOLOGICAL ASPECTS OF *CENTAUREA CYANUS* BIOTYPES RESISTANT TO ALS INHIBITORS

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Abstract

Centaurea cyanus L. is a common field weed in Eastern Europe. In Poland, biotypes of this species with resistance to acetolactate synthase (ALS) inhibitors have been confirmed, and their numbers are increasing. The aim of the study was: (i) to verify the level of resistance to tribenuron-methyl and florasulam and the presence of mutations in the ALS gene of selected populations of C. cyanus, (ii) to check the presence of hormetic reaction of C. cyanus populations to ALS inhibitors, and (iii) to investigate seed germination characteristics of selected C. cyanus populations. Between 2017 and 2021, C. cyanus seed samples were collected from eastern Poland and dose-response studies with tribenuron-methyl and florasulam were performed. High resistance levels to ALS inhibitors were detected in most of the analysed populations, mainly associated with target-site resistance. However, in some individuals from resistant populations, no resistance-related mutations were found in the ALS gene, suggesting that a mixed resistance mechanism may be involved; this assumption requires further investigation. Several ALS inhibitor-resistant populations of C. cyanus exhibited a hormetic response, expressed as increased shoot fresh weight following treatment with tribenuron-methyl or florasulam. The results also demonstrated that the diverse germination behaviour of resistant C. cyanus populations makes it difficult to implement uniform control strategies in agricultural practice. Therefore, an integrated weed management approach is recommended, including practices such as delayed sowing of crops. Additionally, due to the potential hormetic effects of ALS inhibitors, spray drift should be avoided and herbicides should be applied at the recommended field rates, as repeated use of sublethal doses may promote the development of herbicide resistance and stimulate the growth of already resistant C. cyanus plants.

Keywords: *cornflower, ALS inhibitors, target-site resistance, hormesis, germination*

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RESISTANCE OF *PAPAVER RHOEAS* TO ALS INHIBITORS IN POLAND

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Abstract

The spread of herbicide-resistant weed populations is a major challenge for sustainable crop production, and corn poppy (Papaver rhoeas L.) is increasingly affected by this problem. This study aimed to evaluate the susceptibility of Polish P. rhoeas populations to acetolactate synthase (ALS)-inhibiting herbicides and to identify the mechanisms responsible for resistance. Between 2017 and 2020, 157 seed samples were collected across Poland, and dose-response experiments with selected ALS inhibitors were conducted under glasshouse conditions.

Fourteen populations were confirmed as resistant and originated from the Lublin, Świętokrzyskie, Warmia-Mazuria, Lower Silesia and West Pomerania provinces. Resistance was most frequently observed to tribenuron, followed by iodosulfuron in ten populations and florasulam in two populations. ED50 values ranged from 16.3 to 10,212 for tribenuron, from 9.5 to 398.5 for iodosulfuron and from 4.7 to 6.0 for florasulam. Eight populations showed cross-resistance to tribenuron and iodosulfuron, including four classified as highly or very highly resistant to both active substances. Three populations were resistant only to tribenuron, one only to iodosulfuron, one showed reduced susceptibility only to florasulam, and one was resistant to all three herbicides.

Molecular analyses revealed target-site resistance in six of eight analysed resistant populations, caused by mutations at codon 197 of the ALS gene. In one population, the absence of ALS mutations suggests non-target-site resistance, while in another both mechanisms probably coexist. Populations with the NTSR mechanism are very prone to developing resistance to dif-ferent mechanisms of action. Therefore, intensive anti-resistance strategies are needed to limit ALS-inhibitor and multiple resistance in P. rhoeas in Poland.

Keywords: *corn poppy, tribenuron-methyl, iodosulfuron-methyl, florasulam, resistance*

WEED MANAGEMENT STRATEGIES FOR ALS INHIBITOR-RESISTANT *APERA SPICA-VENTI* IN WINTER WHEAT

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Abstract

Apera spica-venti (L.) P.Beauv. is one of the most troublesome grass weeds in European winter cereal production. The increasing occurrence of resistance to acetolactate synthase (ALS)-inhibiting herbicides has substantially reduced the effectiveness of conventional weed control. This study evaluated the efficacy of herbicide programmes differing in herbicide sites of action (HRAC SoA) for the management of ALS inhibitor-resistant A. spica-venti under field conditions.

Field experiments were conducted over two growing seasons at two locations in Poland where resistance to ALS inhibitors had previously been confirmed. Trials were established in a randomized complete block design with four replications. Herbicide efficacy was assessed relative to untreated control plots, and winter wheat grain yield was determined to evaluate the agronomic performance of individual programmes.

The efficacy of weed management strategies strongly depended on the diversity of herbicide sites of action included in the treatment programme. Programmes integrating multiple HRAC groups achieved excellent control, whereas programmes based exclusively on ALS inhibitors (HRAC Group 2) provided poor or inconsistent control of resistant populations. The highest efficacy (98–100%) was obtained with programmes combining prosulfocarb + diflufenican + pinoxaden + clodinafop-propargyl (HRAC Groups 15 + 12 + 1), flufenacet + diflufenican + chlorotoluron (15 + 12 + 5), and chlorotoluron + pinoxaden (5 + 1). Effective weed suppression resulted in significantly higher winter wheat grain yield than in untreated plots.

The results demonstrate that sustainable management of ALS inhibitor-resistant A. spica-venti requires diversified herbicide programmes integrating multiple HRAC sites of action and optimized application timing. Continued reliance on ALS-inhibiting herbicides alone not only fails to provide satisfactory weed control but also increases selection pressure, accelerating the evolution and spread of herbicide-resistant populations.

Keywords: *herbicide resistance, HRAC site of action, herbicide programmes, resistance management, integrated weed management, cereal production*

Acknowledgments: *This research was supported by The National Centre for Research and Development under grant number [BIOSTRATEG 3/347445/1/NCBR/2017].*

WESTERN CORN ROOTWORM LARVAL CONTROL USING AZADIRACHTIN-BASED SEED DRESSING PRODUCTS IN MAIZE

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Abstract

The Western Corn Rootworm (Diabrotica virgifera virgifera LeConte) is one of the most important pests of maize in Hungary. Both larvae and adults are capable of causing significant economic losses; therefore, effective control is essential, particularly in continuous maize cropping systems. The control of larvae is costly, and the extensive use of soil insecticides increases the environmental burden. In recent years, several chemical products used as soil insecticides and seed dressings have been withdrawn from the market, increasing the importance of environmentally friendly biological alternatives. One such biological active ingredient is azadirachtin, an extract obtained from the seeds of Azadirachta indica. In this study, the efficacy of two azadirachtin-based products, NeemAzal T/S (1% azadirachtin; 10 g/L) and NeemAzal F (5% azadirachtin; 50 g/L), applied as seed dressings against Western Corn Rootworm larvae, was evaluated. The products were tested at concentrations ranging from 10% to 150% under different soil conditions and in several regions of Hungary. The results demonstrated that azadirachtin provided effective control of the pest during its larval stage. Treatments with concentrations exceeding 50% consistently achieved effective protection in all experimental replications, indicating that azadirachtin-based seed treatments represent a promising environmentally friendly alternative for the management of Western Corn Rootworm larvae in maize production.

Keywords: *Western Corn Rootworm, azadirachtin, Azadirachta indica, maize, soil pests, biological control methods*

NOVEL APPROACH TO MODELING FOOD CONSUMPTION OF PLODIA INTERPUNCTELLA LARVAE: SHAP INSIGHTS

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Abstract

The Plodia interpunctella (Indian meal moth, IMM) is one of economically most important pests of stored maize worldwide. Biotest was conducted using kernels of 37 Serbian maize genotypes as nutritional and rearing media (whole and crushed/ damaged) for IMM while amount of consumed kernel was recorded across two generations. The obtained empirical data were used for modeling with the aim of identifying the influence of two factors: genotype and kernel state (whole/crushed) on kernel consumption by IMM larvae. A regression-based approach was applied, as it is suitable for analyzing continuous output variables and allows interpretation of the contribution (influence) of individual properties. This approach is particularly important for evaluating the effects of genotypes, which was further enhanced by the application of SHAP (SHapley Additive exPlanations) analysis. The analysis of SHAP values indicated that both, maize genotype and kernel state had great influence on the quantity of consumed kernels by IMM larvae. In addition to ranking variable importance, SHAP analysis enabled the identification of specific genotypes that contribute most to increasing or decreasing the output variable-in this case, the amount of consumed kernels. Practically, the model allows the identification of genotypes that are more palatable to IMM larvae and therefore were more susceptible to IMM attack and at higher risk of facing greater storage losses when infestation occurs. Additionally, the model evaluated the impact of IMM bionomy parameters such as larval body length and fecundity on the output variable (food consumption), and results show that those parameters had a lower impact, as they represent consequences of developmental processes rather than causal factors driving increased feeding. This confirms that the selected model successfully captures the causal drivers of the observed outcome.

Keywords: *Plodia interpunctella, consumed food, SHAP modeling, maize genotype, kernel*

Acknowledgments: *This research was supported by the Science Fund of the Republic of Serbia, #6691, New biorational methods for stored seed pest control and protection: To serve and prevent – SafeSeed, as well as the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant No. 451-03-33/2026-03/200088, 451-03-34/2026-03/200122, 451-03-33/2026-03/ 200032 , and 451-03-137/2025-03/200117).*

CHEMICAL COMPOSITION OF PENNYROYAL (*MENTHA PULEGIUM*) ESSENTIAL OIL AND PHYTOTOXICITY ON RADISH AND BARNYARD GRASS

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Abstract

Pennyroyal (Mentha pulegium) is a good source of essential oils which are considered biological control agents. In this study, we analysed the chemical composition of the root EO using GC/MS. We found that the Pennyroyal EO contains mainly oxygenated monoterpenes: pulegone (79.6%) and isomenthone (5.9%). We also evaluated the phytotoxic activity of the essential oil, formulated as eco-friendly nanoemulsions (Polysorbate 20) at concentrations of 0.001%, 0.005%, 0.01%, 0.1%, and 0.5%, assessing their impact on the early growth dynamics of radish and barnyard grass seedlings. We discovered that the nanoemulsions containing pennyroyal essential oil (EO) exhibit good physicochemical stability. Treatment containing 0.5% essential oil inhibited the growth of barnyard grass seedlings' shoots and roots by 59% and 17%, respectively, while the concentration was effective in killing radish seedlings. Nanoemulsions with EO enhanced total phenolic compounds in radish seedlings but reduced lipids, carbohydrates, and proteins in the storage materials, as shown by FT-Raman spectroscopy. Summing up, the nanoemulsions with pennyroyal EO pose a biochemical stress to the radish and barnyard grass seedlings' initial growth, especially at the biochemical level, pointing to possible allelopathic interactions, which should be further studied in natural conditions.

EFFECT OF BANANA PEEL EXTRACT ON GROWTH PROMOTION AND DISEASE SEVERITY REDUCTION IN BOK CHOY

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Abstract

Brassica crops are economically important vegetables worldwide; however, their productivity is significantly limited by fungal diseases such as Alternaria leaf spot, which reduce both yield and quality. While chemical fungicides remain the primary control method, their excessive use poses environmental risks, human health concerns, and promotes the development of pathogen resistance. Consequently, sustainable and eco-friendly alternatives are urgently required. This study investigated banana peel extract (BPE), a major agricultural waste product in Malaysia as a potential biostimulant and antifungal agent for bok choy (Brassica rapa var. chinensis). Pathogens were isolated and identified as Alternaria alternata by morphology and sequencing (KP739874.1). BPE was prepared using aqueous and ethanolic methods, with antifungal activity tested at 20%, 40%, and 60% concentrations via agar well diffusion assays. Effective treatments were tested in greenhouse trials via foliar spray and soil drench, with controls. Growth parameters, including leaf number, width, and plant height, were recorded weekly, while disease severity, yield, and biomass were assessed at harvest. Results demonstrated concentration-dependent antifungal activity, with the 60% ethanolic extract achieving the highest inhibition. In greenhouse trials, foliar application consistently enhanced plant growth and reduced disease severity more effectively than soil drenching or control treatments. These findings suggest that BPE serves as a low-cost, sustainable strategy for disease management and growth promotion. Repurposing banana waste not only improves vegetable production but also supports circular agricultural waste management. Ultimately, this approach offers a viable, eco-friendly alternative to synthetic chemicals, contributing significantly to more resilient and sustainable agricultural systems worldwide.

Keywords: *Banana peel extract, Alternaria alternata, Biostimulant, Antifungal activity, Sustainable agriculture*

ANTIMICROBIAL POTENTIAL OF BIOGENIC SILVER NANOPARTICLES

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Abstract

Silver nanoparticles (Ag NPs) were synthesized via a green approach using leaf extracts of Ocimum basilicum L. as reducing and stabilizing agents, with silver nitrate serving as the silver precursor. The synthesized Ag NPs were characterized by UV–Vis spectroscopy, dynamic light scattering (DLS), and atomic force microscopy (AFM). Antimicrobial activity assays demonstrated that the Ag NPs exhibited broad-spectrum antibacterial and antifungal effects. Significant antibacterial activity was observed against clinically relevant multidrug-resistant pathogens, including Klebsiella pneumoniae, methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant Enterococcus faecium (VRE), and Enterobacter cloacae, as well as against environmental, commensal, and opportunistic bacterial species such as Stenotrophomonas maltophilia, Kocuria rhizophila, Micrococcus luteus, Bacillus cereus, and Pseudomonas putida. In addition, the AgvNPs inhibited the growth of several economically important plant pathogenic fungi, including Rhizoctonia solani, Fusarium culmorum, Fusarium oxysporum, Microdochium nivale, and Botrytis cinerea. These findings highlight the potential of green-synthesized Ag NPs as promising antimicrobial agents for biomedical and agricultural applications.

Keywords: *antibacterial activities, antifungal activities, green synthesis, silver nanoparticles*

Acknowledgments: *The work was supported by the project VEGA 1/0230/24.*

INFLUENCE OF THE APPLICATION METHOD ON THE ANTIMICROBIAL PROPERTIES OF ZINC OXIDE NANOPARTICLES PREPARED BY GREEN SYNTHESIS

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Abstract

Nanotechnology has experienced rapid development in recent years, and zinc nanoparticles have become an important material used in the fields of medicine, environmental protection, and technological innovation. Their antimicrobial activity, high stability, and ability to modify surface properties provide broad possibilities for various applications. Traditional methods of nanoparticle synthesis often involve procedures that may have a negative impact on the environment. Therefore, increasing attention is being paid to green synthesis methods with a lower ecological impact.

In this work, we focused on the antimicrobial properties of zinc oxide nanoparticles prepared by green synthesis, depending on the method of their application. To determine the antimicrobial effect, diffusion and microdilution methods were used to monitor the activity of ZnO nanoparticles against the bacterial strains Escherichia coli CCM 3954, Pseudomonas syringae CCM 7018, Bacillus subtilis DSM 5552, Micrococcus luteus DSM 1790, and Staphylococcus aureus CCM 4223. Zinc oxide nanoparticles were applied onto the surface of agar plates, incorporated into solid media, and dispersed in liquid nutrient medium.

The results of the individual approaches indicated a significant dependence of the antimicrobial effect on both the application method and the type of microorganism. Agar-based tests primarily enabled the observation of the contact and surface-related effects of ZnO nanoparticles, while in some strains the effect was manifested locally or through changes in colony morphology.

The microdilution method performed in liquid medium demonstrated the inhibitory effect of ZnO nanoparticles at concentrations of 1 mg/mL and 0.5 mg/mL, respectively. The most pronounced inhibitory effect was observed in Staphylococcus aureus and Escherichia coli, whereas Pseudomonas syringae exhibited a high level of tolerance to the tested nanoparticles.

Keywords: *Zinc nanoparticles, green synthesis, antimicrobial effect*

Acknowledgments: *This work was supported by the VEGA 1/0230/24 project.*

SODIUM ALGINATE AS A FUNCTIONAL BIOPOLYMER: FROM STRUCTURE AND PROPERTIES TO FORMULATION SYSTEMS FOR SUSTAINABLE AGRICULTURAL PRODUCTS

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Abstract

Sodium alginate has attracted increasing interest in recent years and has been extensively investigated across various scientific fields for its physicochemical properties and potential applications, particularly as a sustainable alternative to synthetic polymers in different product formulations.

Agriculture has also benefited from this research direction, with scientists in this field and related areas, including agricultural input industries, identifying numerous properties and applications of sodium alginate. Several studies have demonstrated that sodium alginate can be effectively incorporated into formulations for a wide range of agricultural products. It has been successfully applied in hydrogels, mulch films, and microcapsules, where it has shown considerable versatility and potential as a sustainable alternative to synthetic polymers. Furthermore, sodium alginate is frequently combined with other biopolymers, such as chitosan and nanocellulose, to form matrices for the encapsulation of compounds with prophylactic, stimulatory, or fertilizing functions for crop plants.

The present study aims to summarize the properties reported to date and to provide the basis for future research, given that the agricultural applications of this biopolymer remain relatively recent and insufficiently explored.

Keywords: *sodium alginate, sustainable agriculture, microencapsulation, biodegradable formulations*

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MITIGATING PESTICIDE POLLUTION: A KEY STEP TOWARD AGRICULTURE SUSTAINABILITY

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Abstract

Toxic substances, including pesticide residues, are increasingly detected in air, water, soil, plants, food, and animal feed. These contaminants can enter the food chain, accumulate in humans and animals, and adversely affect ecological balance and public health. Numerous studies have shown that a wide range of pesticides residues persist in soils, agricultural products, water bodies, and sediments, posing long-term risks to ecosystems and human well-being. Their physicochemical properties, such as water solubility, thermal stability, and environmental persistence, enhance their mobility and prolong their detrimental effects. Global concerns are growing due to decline in soil biodiversity and food safety, intensified by pesticide contamination. All pesticides are bioactive substances that pose risks and hazards. Pesticides can be water soluble and thermally stable, which can prolong their detrimental effects on the environment. Strategies aimed at reducing pesticide-related impacts include the adoption of integrated pest management, the development and use of biopesticides, precision application technologies, and environmentally safer formulations. These approaches seek to minimize chemical inputs while maintaining crop productivity and protecting soil and water quality. Enhanced environmental monitoring and a comprehensive understanding of pesticide residues fate, transport, and degradation routes are essential for formulating effective mitigation strategies and evidence-based agricultural practices. Therefore, reducing pesticide pollution is essential for safeguarding biodiversity, preserving ecosystem services, and aligning agricultural production with environmental protection and public health objectives.

Keywords: *pesticide pollution, sustainable agriculture, environmental contamination, integrated pest management, biopesticides.*

ENHANCING NATURE-BASED PROCESSES THROUGH MANAGEMENT PRACTICES BOOST ECOSYSTEM SERVICES IN WOODY CROPS

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Abstract

Woody cropping systems, particularly Mediterranean olive orchards, are facing increasing pressure from soil degradation, biodiversity loss and climate change. In this context, management practices that enhance nature-based processes (NBPs) have emerged as an effective pathway to improve the multifunctionality and resilience of agroecosystems while maintaining agricultural productivity. This study evaluates how the intensification of ecological processes through sustainable management contributes to the provision of multiple ecosystem services in woody crops.

Results in 24 commercial olive groves consistently indicate that management practices promoting NBPs significantly improve soil organic carbon accumulation, stimulate soil biological activity and reduce erosion risk compared with conventional management. These ecological improvements strengthen regulating and supporting ecosystem services while contributing to climate change mitigation through increased carbon storage.

Our findings support the hypothesis that ecosystem services in woody crops are primarily enhanced by strengthening ecological processes rather than increasing external inputs. This process-based perspective provides robust scientific evidence for the implementation of Nature-based Solutions in Mediterranean agriculture and contributes to the development of management strategies aligned with the European Green Deal, the EU Soil Strategy and emerging carbon farming initiatives.

Keywords: *Olive groves, ecosystems services*

APPLICATION OF HIGH-RESOLUTION ORTHOPHOTOGRAPHY FOR CROP CLASSIFICATION: ACCURACY ANALYSIS IN THE CONTEXT OF AGROECOLOGICAL RESEARCH

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Abstract

High-resolution orthophotography has become an essential data source in agroecological research, enabling detailed land cover and crop classification. This study evaluates the effectiveness of high-resolution orthophotography for crop classification using four supervised machine learning algorithms: Support Vector Machine (SVM), k-Nearest Neighbors (KNN), Random Trees (RT), and Maximum Likelihood (ML). Classification performance was assessed using confusion matrices, overall accuracy, user's and producer's accuracies, and the Kappa coefficient. The results indicate that the Random Trees algorithm achieved the highest overall accuracy (67.68%) and Kappa coefficient (63.64), outperforming SVM (62.63%), ML (61.62%), and KNN (60.61%). Despite relatively high classification accuracy for distinct classes such as water bodies and rapeseed, lower accuracies were observed for complex classes like roads, built-up areas, and mixed vegetation. The findings highlight both the potential and limitations of orthophotography data in agroecological classification tasks, emphasizing the importance of algorithm selection and class separability.

Keywords: *orthophotography, crop classification, classification accuracy, machine learning methods, ArcGIS Pro*

EXPLAINABLE AI FOR DEPTH-SPECIFIC SOIL MOISTURE PREDICTION USING SENTINEL-2 AND IOT DATA IN PRECISION AGRICULTURE

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Abstract

Accurate soil moisture monitoring across the root zone is essential for precision irrigation, sustainable water management, and climate-resilient crop production. This conference presentation summarizes the results of a recently published study that developed an explainable machine learning framework for depth-specific soil moisture content prediction in agricultural soils. The study integrated Sentinel-2-derived vegetation indices, namely the Normalized Difference Vegetation Index and Normalized Difference Moisture Index, with Internet of Things-based meteorological data to predict gravimetrically measured soil moisture content at five depths: 5, 20, 40, 60, and 80 cm. Separate XGBoost models were developed for loam and silt loam soils under two input scenarios: vegetation indices only, and combined vegetation indices with meteorological variables.

The results showed that combining Sentinel-2 and IoT-derived meteorological data substantially improved prediction accuracy compared with the use of vegetation indices alone. The improvement was particularly evident in loam soil at shallow depths, where the combined model increased prediction performance and reduced error. In silt loam soil, the model achieved very high accuracy, with coefficient of determination values reaching up to 0.99 at shallow depths. Explainability analysis using SHapley Additive exPlanations revealed that NDVI was the dominant predictor in the upper soil layers, reflecting the relationship between canopy vigor and near-surface water availability. In contrast, solar radiation and other meteorological variables became more influential at deeper layers, highlighting the role of atmospheric evaporative demand and soil–plant water dynamics.

These findings demonstrate the potential of combining satellite vegetation indicators, field-based IoT data, and explainable artificial intelligence for practical soil moisture assessment. The approach can support depth-specific irrigation decisions, improve agricultural water-use efficiency, and contribute to sustainable and climate-smart crop management. The presentation will focus on the methodological workflow, key model performance results, SHAP-based interpretation, and the practical implications for precision irrigation in maize production systems.

Keywords: *soil moisture prediction; Sentinel-2; IoT; XGBoost; SHAP; precision irrigation; digital agriculture*

PROTEOLYTIC POTENTIAL OF DIFFERENT LEGUME SPECIES HERBAGES

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Abstract

The aim of the study was to compare the proteolytic potential of selected legume species during ensiling by determining the degree of proteolysis. The experimental material consisted of herbage of alfalfa, red clover, white clover, alsike clover, Persian clover and birdsfoot trefoil harvested at the beginning of flowering. The plant material was ensiled on a laboratory scale in vacuum-sealed bags. Samples of fresh herbage and silages after 120 days of storage were analysed for chemical composition and true protein content using trichloroacetic acid (TCA). The degree of proteolysis was calculated as the ratio of true protein content in silage to that in fresh herbage. The data were analysed by one-way ANOVA, and differences between means were determined using Duncan's test. Significant differences were found in crude protein content among the tested legume species ($P < 0.01$). The highest crude protein content was observed in white clover, alsike clover and Persian clover. However, alsike and Persian clover were characterized by the lowest proportion of true protein in crude protein. The degree of proteolysis during ensiling also differed significantly among species ($P < 0.01$). The most favourable degree of proteolysis was observed in alsike clover, followed by red clover, white clover, Persian clover and alfalfa. The greatest protein degradation was found in birdsfoot trefoil, where the degree of proteolysis reached 42%. The results indicate that alsike and Persian clover combine high crude protein content with relatively low protein degradation during ensiling. In contrast, birdsfoot trefoil protein was the most susceptible to proteolytic degradation.

Keywords: *legumes, ensiling, proteolysis, true protein, crude protein, silage quality*

ALTERNATIVE FEED RESOURCES FOR SUSTAINABLE ANIMAL PRODUCTION

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Abstract

The sustainability of animal production systems is increasingly challenged by growing global demand for animal-derived products, limited natural resources, climate change, and competition between feed and food production. Conventional feed ingredients, particularly protein-rich raw materials, are associated with substantial environmental burdens and market vulnerabilities, leading to the need for more sustainable and resilient feeding strategies. As a result, alternative feed resources have attracted considerable scientific and industrial interest as potential components of future animal nutrition systems. A wide range of alternative feed materials, including insects, algae, agricultural by-products, former food products, and other novel protein sources, have been investigated for their nutritional, environmental, and economic potential. These resources may contribute to improved nutrient-use efficiency, reduced dependence on conventional feed ingredients, and enhanced circularity within agri-food systems. Furthermore, their utilization may support waste valorization and reduce pressure on land, water, and other critical resources. Despite their potential benefits, the successful implementation of alternative feed resources requires careful evaluation of nutritional quality, digestibility, safety, variability in chemical composition, anti-nutritional factors, and species-specific physiological responses. Regulatory frameworks, consumer acceptance, economic feasibility, and scalability also remain important considerations influencing their practical adoption. Current evidence suggests that alternative feed resources can play a significant role in improving the sustainability and resilience of animal production systems. Continued research and technological innovation are necessary to optimize their application, ensure product safety and quality, and facilitate their integration into livestock feeding strategies that support environmental, economic, and social sustainability.

Keywords: *alternative feed resources, animal nutrition, sustainable livestock production, circular economy, novel protein sources, feed sustainability, resource efficiency, livestock systems.*

HEMP SEED (*CANNABIS SATIVA L.*) IN CATTLE NUTRITION: EFFECTS ON BEEF FATTY ACID PROFILE, RETINOL, AND α-TOCOPHEROL CONCENTRATIONS

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Abstract

This study evaluated the effects of dietary supplementation with whole hemp seeds (Cannabis sativa L.) on intramuscular fat (IMF) fatty acid composition and on retinol and α-tocopherol concentrations in Holstein–Friesian (HF) bulls. Twenty-four HF bulls (≈719 days old) were assigned (analogue method) to three treatments (n = 8). The 91-day feeding trial used maize silage ad libitum and up to 5 kg/day of a concentrate based on triticale meal, rapeseed meal, and a vitamin–mineral premix, with hemp seeds included according to treatment (a control group without hemp seeds in the diet and diets containing hemp seeds at 10% or 17%). After slaughter, the longissimus lumborum and semimembranosus muscles were sampled and analyzed for IMF content, fatty acid profile (PN-EN ISO 5509:2001; PN-EN ISO 5508:1996), and retinol and α-tocopherol concentrations (PN-EN 12822; PN-EN 12823-1); data were processed using Statistica. Hemp seed inclusion significantly reduced meat retinol content (p = 0.001), irrespective of muscle type, and increased α-tocopherol concentration (p = 0.001), with a clear muscle-type effect. IMF content was not significantly affected; however, hemp seeds shifted the fatty acid profile toward a higher proportion of unsaturated fractions, reflected by lower SFA and higher UFA/MUFA and PUFA/SFA ratios. Muscle type strongly influenced PUFA levels, including n-3 and n-6 fractions, which were higher in the semimembranosus. Overall, hemp seed supplementation may enhance the antioxidant potential of beef (vitamin E) without parallel enrichment in vitamin A, and the success of nutritional lipid "enrichment" depends on the specific muscle and its metabolic characteristics.

Keywords: *hemp seed, Cannabis sativa L., fatty acid profile, beef quality*

Acknowledgments: *Funded by the Minister of Science under „the Regional Initiative of Excellence Program"*

EVALUATION OF THE EFFECT OF BOLUSES CONTAINING PLANT ESSENTIAL OILS ON REDUCING THE RISK OF SUBACUTE RUMINAL ACIDOSIS AND IMPROVING PRODUCTION PERFORMANCE IN DAIRY COWS

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Abstract

The aim of the study was to evaluate the effects of intraruminal boluses containing a blend of essential oils (eugenol and capsaicin), developed based on previous in vitro studies, on milk yield.

Two experiments were conducted: the first was a pilot design with six cows divided into two groups, and the second experiment involved a larger group of 2 x 20 cows. The groups were: Control – without boluses and Bol – with boluses added after calving. In both experiments the multiparous cows were divided into groups as analogs on the basis of years and milk yield during the previous lactation, which did not differ between the groups (P>0.05). The cows received ad libitum a partial mixed ration (PMR), which was served twice a day and met the requirements for 25 kg of milk yield and concentrate in accordance with individual milk yield (NRC, 2001). The cows were milked in an automatic milking system (AMS, Astronaut, Lely Industries, NV, Maassluis, The Netherlands). Results were processed statistically using Student's t-test with the PROC TTEST procedure of the SAS 9.4 (2004) SAS®/STAT software package (SAS Institute Inc., Cary, NC, USA). To interpret the results, the following criteria of significance were used: significant (P ≤ 0.05) and non-significant (P > 0.05).

In the first experiment, intraruminal boluses significantly increased milk yield (P < 0.01). However, this effect was not confirmed in the second part of the study, where no significant improvement in milk production was observed (P > 0.05).

Given the contrasting thermal conditions, under which the two experiments were conducted (summer vs. winter), we hypothesize that the positive effect of the boluses observed in the first experiment was associated with their action under heat stress. In the second experiment, however, more favorable environmental conditions may have masked this effect, preventing its detection. Nevertheless, this hypothesis requires further verification.

Keywords: *Dairy cow, SARA, essential oils, eugenol, capsaicin, milk production*

Acknowledgments: *This research was funded by the National Centre for Research and Development within the framework of the Smart Growth Operational Programme (POIR.01.01.01-00-0322/17)*

THE EFFECT OF HIGH-PROTEIN ORGANIC FEEDS IN PIG DIETS ON SLAUGHTER AND CARCASS CHARACTERISTICS, AND THE FATTY ACID PROFILE OF MEAT

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Abstract

The objective of the study was to evaluate the effect of selected organic high-protein feeds (rapeseed cake, extruded soybeans, faba bean, and pea seeds) on slaughter and carcass characteristics and the fatty acid profile of meat from native breed fatteners.

The study was conducted on 32 fatteners of the Puławska and Złotnicka Pstra breeds (16 animals per breed). Animals with an initial body weight of 25–30 kg were kept until reaching slaughter weight (115–130 kg) on a certified organic farm. The fatteners were divided into four feeding groups: Group I (control) – fed standard organic feed mixtures with rapeseed cake as the main protein source; Group II – fed a mixture containing 10% extruded soybeans; Group III – fed a mixture with protein from low-tannin faba bean seeds; and Group IV – fed a mixture with protein from pea seeds. Following slaughter, carcass characteristics were determined, and meat samples were collected for chemical analysis. The fatty acid profile was determined in the intramuscular fat using gas chromatography (Varian CP-3800).

It was shown that the use of extruded soybeans (Group II) had the most beneficial effect on carcass characteristics, improving them or maintaining them at a level similar to the control group. Breed proved to be the main factor determining carcass characteristics, with Złotnicka Pstra fatteners showing higher carcass lean meat content. The inclusion of extruded soybeans in the diets promoted an increase in the level of polyunsaturated fatty acids (PUFA) in the loin and ham, whereas the inclusion of peas increased the content of saturated fatty acids (SFA). The effect of breed on the fatty acid profile was less significant than the dietary factor; however, a more favorable n-6/n-3 ratio was observed in the loin of the Puławska breed.

The research results confirm the high suitability of native protein feeds in organic pig fattening, allowing for the production of raw material with good carcass parameters and a desirable fatty acid profile.

Keywords: *native breeds (Puławska, Złotnicka Spotted), organic protein feeds, slaughter traits, fatty acid profile*

Acknowledgments: *This research was funded by the Ministry of Agriculture and Rural Development of Poland (Decision No. DEJ.re.765.12.2025) as part of the project: "Animal production by organic methods: Research on the development of effective production methods for high-protein organic feed components for pigs and poultry".*

THE EFFECT OF DIETARY *CLITORIA TERNATEA* L. SUPPLEMENTATION ON THE CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF PORK

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Abstract

Phytobiotics, due to potential health-promoting properties, are increasingly used in farm animal nutrition. One such is Clitoria ternatea L. Numerous studies have demonstrated its' phytobiotic potential, associated with the presence of various bioactive compounds, including alkaloids, tannins, glycosides, resins, steroids, saponins, flavonoids and phenolic compounds. Owing to these properties, Clitoria ternatea has potential application as a natural feed additive in animal production.

The aim of the study was to assess the effect of Clitoria ternatea aqueous extract addition on the chemical composition of pork meat of fattening pigs of the Puławska breed. The experiment was conducted on pigs assigned to a control group and an experimental one (n=10 each). Both groups were fed the same diet. Animals in the experimental group received dietary supplementation of an aqueous extract of Clitoria ternatea L. at a dose of 300 mg per kg of body weight per day. Chemical analyses were performed on selected pork cuts, including loin, ham, neck, shoulder and belly. The basic composition of meat was determined. The fatty acid profile of the fat was analysed by gas chromatography.

The results indicated that dietary supplementation with Clitoria ternatea had a limited effect on dry matter, crude ash, and crude protein content, with comparable values observed in both groups, although slightly higher protein levels were noted in the experimental group for neck and belly. In contrast, crude fat content was slightly higher in the analysed pork cuts from the experimental group, with the most pronounced differences observed in the neck and belly. However, noticeable changes were noted in the fatty acid profile of the intramuscular fat of the analysed cuts.

In conclusion, dietary inclusion of Clitoria ternatea L. slightly influenced the chemical composition of pork of Puławska breed pigs, mainly by modulating fat content and fatty acid composition.

Keywords: *Clitoria ternatea L., nutrition, pigs, pork, meat quality, fatty acids*

CONSERVATION OF SLOVAK NATIVE SHEEP BREEDS THROUGH STEM CELL BANKING

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Abstract

The main objective of this study was to optimize isolation, characterization and cryoconservation of mesenchymal stem cells (MSCs) derived from bone marrow (BM) and adipose tissue (AT) of endangered Slovak native sheep breeds (Native Wallachian and Slovak dairy sheep) to preserve their valuable genetic material for future generations. MSCs from bone marrow were successfully isolated using density gradient centrifugation and plastic adherence method as well as MSCs from AT, which were obtained from tissue using enzymatic digestion prior to the final cell seeding. Both cultured cell types showed spindle-shaped morphology with sufficient proliferation rate and exhibited more than 18 positive surface and intracellular MSCs markers. Moreover, cells were expanded till passage 8 with stable cell cycle and karyotype showing high viability and low apoptosis rate. Both MSCs types displayed typical three-lineage differentiation ability and neuron-like cells transdifferentiation potential. MSCs in passage 3 were successfully cryopreserved and stored for more than 1.5 years in liquid nitrogen with subsequent thawing, after which cells remained high (over 90%) viability and proliferation ability. In conclusion, till now we have continuously frozen and stored in animal stem cell bank, which is a part of animal gene bank at NPPC, several cryotubes of mesenchymal stem cells from more than six individual animals from each breed containing cells from different cell passages.

Keywords: *Native Wallachian sheep, Slovak dairy sheep, mesenchymal stem cells, bone marrow, adipose tissue, cryopreservation*

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BETWEEN SURVIVAL AND EXTINCTION: SUSTAINABILITY OF THE NATIVE LIPE SHEEP

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Abstract

The native Lipe sheep, an indigenous breed historically rooted in the Danube valley in the village of Lipe, Central Serbia. The breed belongs to the Zackel group of sheep (Pramenka) and represents both a cultural heritage asset and a genetic reservoir uniquely adapted to the local environmental conditions. It is a local type of sheep and represents 2% of the controlled Pramenka population in Serbia evidented in the Herd Book. However, in recent decades, the breed has faced a sharp population decline (in 2008. the population size was 200 breeding animals) driven by agricultural intensification, rural depopulation, and the increasing dominance of high-yield commercial breeds. In 2024. there were 2102 breeding animals under production control in the Herd book. This paper examines the sustainability of the Lipe sheep at the intersection of ecological resilience, economic viability, and cultural preservation, asking whether the breed can persist under current pressures or is approaching irreversible extinction.

Drawing on fieldwork, farmer interviews, and analysis of breeding records, the study identifies the primary factors contributing to the decline of Lipe sheep populations. These include low market competitiveness due to reduced meat and milk yields in comparation to the exotic breeds, and limited policy support. At the same time, the research highlights the breed's significant adaptive traits, including disease resistance, low-input feeding requirements, and the ability to thrive on marginal pastures unsuitable for intensive agriculture. These characteristics position the Lipe sheep as a potentially valuable resource in the context of climate change and the transition toward more sustainable, low-impact farming systems.

Breeding of the Lipe sheepp has a strong socio-economic dimension, emphasizing the role of smallholder farmers as custodians of genetic diversity. The breeding has challenges including aging rural populations, insufficient financial incentives, and weak market integration for traditional products. Case studies of successful niche-market initiatives—such as labeling schemes, local branding of lamb products, and agro-tourism—demonstrate that economic sustainability can be enhanced when cultural and ecological values are effectively communicated to consumers.

In addition, efforts are made to the conservation strategies, including in situ and ex situ approaches, and identification of gaps in coordination between governmental agencies, research institutions, and farming communities. It argues for a more integrated framework that combines genetic conservation with rural development policies, education, and targeted subsidies.

Ultimately, the sustainability of the Lipe sheep depends on a multi-dimensional approach that transcends purely agricultural considerations. Preserving this breed is not only a matter of maintaining biodiversity but also of safeguarding cultural identity and supporting resilient rural livelihoods. The paper concludes that while two decades ago the Lipe sheep was at a critical threshold, it is now with

stable population status, but needs constant efforts for survival. With strategic intervention, increased awareness, and alignment of economic incentives with conservation goals, the breed can transition from a trajectory of decline toward one of sustainable survival.

Keywords: *Lipe sheep, native, sustainability, conservation, rural development, cultural heritage*

Acknowledgments: *The study was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract number 451-03-34/2026-03/200143).*

ASSESSMENT OF MORPHOMETRIC TRAITS AND BREED QUALITY IN CALIFORNIAN AND BURGUNDY RABBITS

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Abstract

The aim of this study was to assess morphometric traits and breed quality characteristics of two medium-sized rabbit breeds, Californian and Burgundy rabbits, reared under Lithuanian breeding conditions. The study involved 30 purebred rabbits exhibited at a breeding rabbit exhibition, including 15 Californian and 15 Burgundy rabbits aged 8–9 months. Exterior characteristics, constitution type, coat density, morphometric measurements, body indices, and breed evaluation scores were assessed using standardized breeding methodologies. Statistical analysis was performed using the Mann–Whitney U test. The evaluation of exterior traits revealed only minor defects, primarily among Burgundy rabbits, while all animals exhibited a strong constitution and dense coat. Significant breed-related differences ($P<0.05$) were identified for several morphometric traits, including occipital height, chest depth, abdominal circumference, shoulder width, ear dimensions, head measurements, limb lengths, tibia length, thigh circumference, and tail length. Burgundy rabbits generally showed larger values for most of these measurements. Among the calculated body indices, only the body shape index differed significantly between breeds, being higher in Californian rabbits ($P<0.05$). Assessment of breed quality demonstrated high evaluation scores in both breeds, with no significant differences observed between breeds or sexes ($P>0.05$). All rabbits were classified in the highest breeding quality category ("very good"), indicating good conformity to breed standards. The results demonstrate that although morphometric differences exist between Californian and Burgundy rabbits, both breeds exhibit similarly high breeding quality and suitability for breeding programs and exhibition purposes.

Keywords: *rabbit breeding, morphometric measurements, breed evaluation, breeding quality, Californian rabbit, Burgundy rabbit, body indices*

EFFECTS OF GENOTYPE ON MEAT QUALITY TRAITS IN BROILER CHICKENS

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Abstract

Broiler genotype is an important factor influencing meat quality characteristics and consumer acceptance of poultry products. Understanding genotype-related differences in meat composition and technological quality is essential for selecting production systems that meet both industry requirements and consumer expectations. Therefore, the aim of the recent study was to compare meat quality traits in Ross 308 and Sasso broiler chickens. After slaughter, samples of the breast, thigh, and drumstick were analyzed for physicochemical and technological meat quality parameters. These included dry matter, protein, intramuscular fat, pH, ash, wateriness, water-holding capacity, cooking losses, and color characteristics. Sensory evaluation was performed using trained assessors, and emotional responses were assessed using FaceReader software. Significant genotype-related differences were observed in several meat quality characteristics. Compared with Ross 308 broilers, Sasso broiler meat contained higher levels of dry matter and protein and exhibited lower cooking losses ($P < 0.05$). Meat pH values were similar between genotypes, while Ross 308 meat showed a slightly higher water-holding capacity. However, this difference was not statistically significant ($P > 0.05$). Significant differences were also observed in color characteristics. Ross 308 meat was lighter, whereas Sasso meat was characterized by greater redness ($P < 0.05$). These characteristics are commonly associated with differences in technological quality and consumer perception of poultry meat. Sensory assessment revealed predominantly neutral emotional responses for both samples, and no clear preference for either genotype was identified. In general, recent findings demonstrate that broiler genotype significantly influences meat quality characteristics. Sasso broilers exhibited several favorable compositional and technological meat quality traits, while Ross 308 broilers produced lighter-colored meat. These results highlight the importance of genotype selection when targeting specific quality attributes in poultry production systems.

Keywords: *broiler chickens, genotype, meat quality, Ross 308, Sasso, technological quality, color traits, sensory evaluation.*

MOLECULAR PROFILING FOR TIMING OF CATCH DAMAGE IN BROILER CHICKEN

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Abstract

Catch damage, defined as physical injuries occurring during catching and related preslaughter handling, represents a major animal welfare concern in modern broiler production and is associated with economic losses due to carcass downgrades and condemnations. Despite its importance, assessment of catch damage across the poultry industry remains methodologically inconsistent. Most evaluations rely on post-mortem visual inspection at slaughter, which does not allow reliable differentiation between injuries sustained during catching and those originating earlier during rearing or later during transport and processing. Furthermore, standardized approaches to determine the timing of tissue damage are lacking, limiting both scientific comparability and objective attribution of responsibility within the production chain. This review proposes a molecular and biochemical framework to estimate the age of bruises and soft tissue injuries in broiler chickens, providing a biologically grounded approach to timing catch-related damage. The methodology integrates quantitative profiling of heme degradation products (biliverdin and bilirubin) using LC–MS/MS, assessment of hemoglobin oxidation state (%methemoglobin) by UV–Vis spectrophotometry, and measurement of total hemoglobin content as an indicator of early hemorrhage. These core markers are complemented by inflammatory and tissue-remodeling responses evaluated through cytokine protein quantification and gene expression analysis. Together, these parameters reflect sequential stages of hemorrhage resolution and inflammatory dynamics, enabling discrimination between very recent (hours), intermediate (1–2 days), and older (2–4 days) lesions. The proposed approach aims to provide an objective tool for injury timing, supporting welfare assessment, research standardization, and improved management decisions. This molecular methodology is currently under experimental testing and validation, and its practical applicability under commercial conditions is being evaluated.

Keywords: *broiler chickens, catch damage, animal welfare, bruise age estimation, molecular biomarkers, preslaughter handling, poultry industry*

Acknowledgments: *This research was supported by the project Animal Welfare Indicators at the Slaughter House (aWISH), Grant Agreement ID: 101060818, HORIZON programme.*

IMPACT OF PRODUCTION SYSTEM ON PORK LOIN QUALITY

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Abstract

In recent decades, there has been a steady increase in interest in organic food in Europe, as reflected in the growing demand for such products. This trend is primarily driven by increased consumer awareness, greater attention to food quality, and concerns regarding environmental protection and animal welfare. However, despite the growing popularity of this market segment, studies comparing organic and conventional products remain inconclusive, indicating the need for further research to better understand the differences between production systems and the factors influencing consumer choices. The aim of this study was to compare selected quality characteristics of retail pork from conventionally and organically reared pigs. The study material consisted of loins obtained from the progeny of Polish Large White sires and Puławska dams, collected directly from an abattoir 24 hours post-slaughter. Twelve samples originated from fatteners raised under the conventional system, while the remaining twelve were derived from animals reared under a certified organic system. Higher pH24 values were observed in organic loins compared to conventional ones (5.6 vs. 5.5). Additionally, organic loins exhibited a more intense red colour than those from conventional production. Conventional samples showed higher fat content, drip loss, and cooking loss. Protein content did not differ between husbandry systems. The proportion of saturated fatty acids was higher in conventionally produced meat compared to organically produced meat (42.6% vs. 39.8%). In contrast, organically produced pork exhibited a higher proportion of monounsaturated fatty acids (48.6% vs. 45.4%). In conclusion, meat from conventionally raised pigs was characterized by lower pH_{24} and higher drip loss, indicating reduced meat quality. Meat from organically raised pigs contained less total fat and fewer saturated fatty acids, while showing a higher proportion of monounsaturated fatty acids. Thus, it proved to be more beneficial from a human health perspective.

Keywords: *organic farming, conventional farming, pork quality, technological properties, chemical composition*

CARCASS TRAITS AND SELECTED PHYSICOCHEMICAL PROPERTIES OF MEAT FROM WILD GEESE HUNTED IN POLAND

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Abstract

The aim of this study was to characterize carcass traits and selected physicochemical properties of meat from wild geese hunted in Poland in relation to domestic geese. The study included 45 male geese: three species of wild geese – Greater White-fronted Goose (Anser albifrons), Greylag Goose (Anser anser), and Bean Goose (Anser fabalis) and two domestic breeds – White Kołuda® and Biłgorajska (n = 9 per group). Carcass traits were determined, and breast and leg muscles were analysed for proximate composition, pH at 72 h post mortem and after frozen storage, CIE colour indices, total heme pigments, and lipid oxidation expressed as TBARS.

Among the wild species, Greylag Goose showed the highest body weight, empty body weight, and the greatest weights of edible carcass components, whereas Greater White-fronted Goose had the lowest values. White Kołuda® (WK), compared with the wild geese, displayed the greatest total body weight and the heaviest edible parts; however, the percentage of breast muscle was approximately twice as high in the wild birds. In breast muscle, Greylag and Bean geese contained more protein than Greater White-fronted Goose, while Bean Goose leg muscles had the highest fat content and energy value among the wild species. Compared with domestic geese, especially WK, meat from wild birds had lower moisture and fat contents but higher pH. Wild goose meat was also darker, contained more heme pigments, and showed higher TBARS values.

The results demonstrate clear interspecific differences in carcass characteristics and meat quality among species of wild geese and substantial differences between bird types (wild vs. domestic), indicating that meat from hunted wild geese is a distinct and valuable raw material. These findings also broaden current knowledge of the slaughter traits and meat quality of European wild geese.

Keywords: *carcass characteristics, goose meat, meat quality, proximate composition, colour*

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EVALUATION OF THE QUALITY ATTRIBUTES AND PHYSICOCHEMICAL PROPERTIES OF YOGURTS MADE FROM COW, GOAT, AND MIXED MILK

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Abstract

The incorporation of mixed cow and goat milk in yogurt production facilitates the optimization of fermentation performance, textural characteristics, and sensory qualities. This study investigated the fermentation dynamics and physicochemical, microbiological, textural, and color attributes of yogurts produced from cow milk (A), mixed cow–goat milk at volume ratios of 75:25 (B), 50:50 (C), 25:75 (D), and goat milk (E). Volatile organic compounds (VOCs) were analyzed in milk before fermentation, as well as in yogurts following production and after two weeks of refrigerated storage. Sensory properties were evaluated after two weeks of storage. Increasing the proportion of goat milk in the blend reduced fermentation time, while a higher proportion of cow milk promoted lactic acid bacteria (LAB) survival, and improved textural strength. Yogurts with greater goat milk content exhibited increased lightness and whiteness. The type of milk significantly affected chemical composition, with goat milk yogurts displaying higher fat and lower lactose content. Among the mixed-milk yogurts, the sample containing 25% goat milk (B) received the highest sensory acceptance. Overall, the findings indicate that cow–goat mixed-milk yogurts offer a balanced compromise between textural stability, microbial viability, and sensory acceptance.

Keywords: *goat milk, cow milk, yogurt, sensory analysis*

SENSORY AND MICROBIOLOGICAL CHARACTERISTICS OF YOGHURTS MADE FROM GOAT AND COW MILK

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Abstract

Goat's milk yoghurts are characterised by high nutritional value; however, they often exhibit a distinctive taste and aroma that are not always accepted by consumers, as well as a soft curd structure and a tendency to syneresis during storage. The aim of this study was to develop a yoghurt with improved sensory characteristics that would be acceptable to consumers. The study included yoghurts produced from goat's milk, mixtures of goat's and cow's milk at different v/v ratios (3:1, 1:1, 1:3), and cow's milk, using a starter culture (YC-X16, Novonesis, Czosnów, Poland). Milk was pasteurised at 95°C for 5 minutes and standardised to 15% total solids using goat's or cow's milk powder, respectively. Fermentation was conducted at 43°C until a pH of 4.6 was reached, after which the yoghurts were stored at 4°C. Product quality was evaluated by determining titratable acidity and microbial counts, including Lactobacillus delbrueckii subsp. bulgaricus (MRS medium, Merck, Darmstadt), Streptococcus thermophilus (M17 medium, Merck, Darmstadt), and Enterobacteriaceae (VRBG medium, Merck, Darmstadt). Sensory analysis was performed using a 7-point hedonic scale. Analyses were conducted after 2, 7, and 14 days of storage at 4°C. The results showed that increasing the proportion of cow's milk in the formulation prolonged the fermentation time. The acidity of all yoghurts increased during storage. The number of Lactobacillus delbrueckii subsp. bulgaricus decreased significantly ($p < 0.05$). However, after 14 days of storage, the counts of L. delbrueckii subsp. bulgaricus and Streptococcus thermophilus remained at levels consistent with FAO/WHO recommendations. The addition of cow's milk improved the sensory quality of the yoghurts. The highest sensory scores were obtained for yoghurts produced from a goat's and cow's milk mixture at a ratio of 1:3 (v/v).

Keywords: *goat milk, microbiology, sensory analysis*

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CHARACTERISTICS OF FRESH CHEESES WITH DIFFERENT FAT CONTENT

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Abstract

The aim of this study was to characterize acid coagulated cheese with varying fat contents (4.0%, 7.5%, and 10.0%), and mascarpone cheese with a fat content of 40.0%. The dry matter content and the pH within the range of 4.45–4.62 increased with the increase in fat content in acid coagulated cheeses, whereas mascarpone, due to a different method of protein coagulation (thermal-acid), was characterized by a higher pH (6.42). Modifications in composition and production methods influenced the color, texture, microstructure, and the sensory properties of fresh cheeses.

An increase in color saturation and a decrease in the whiteness index of acid coagulated cheeses were observed with increasing fat and dry matter content. The color parameters a (negative values) and b* (positive values) and the color saturation of mascarpone reached higher values compared to acid coagulated cheeses. The hardness and penetration force of mascarpone were approximately 10 times higher than those of acid coagulated cheeses. The microstructure of mascarpone was regular with small voids, whereas acid coagulated cheeses were characterized by looser cross-linking and larger voids.*

Sensory analysis revealed a uniform color, a smooth texture, and a milky and creamy taste and aroma; in the case of mascarpone, it was also sweet. All cheeses received an overall rating of "very good". The results of the sensory analysis regarding color and texture were consistent with the results of the instrumental measurements.

Keywords: *acid coagulated cheese, mascarpone, color, texture, microstructure, sensory analysis*

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THE EFFECT OF HIGH PRESSURE ON SELECTED PROPERTIES OF GOAT MILK

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Abstract

The effect of high-pressure processing (200–500 MPa) on selected microbiological, physicochemical, and technological properties of goat milk during refrigerated storage (14 days, 4°C) was investigated. Milk samples were subjected to high-pressure treatment at 20°C for 15 min and analyzed immediately after processing and during storage. High-pressure treatment significantly reduced the total viable count of bacteria, with the most pronounced effect observed at pressures ≥400 MPa ($P < 0.05$). However, partial microbial recovery occurred during storage. High-pressure processing increased particle size and protein content. In untreated milk, particle size increased during storage ($P < 0.05$), whereas high pressure minimized or prevented these changes, particularly at pressures ≥400 MPa. The total colour difference between untreated and treated samples increased with pressure ($P < 0.05$) and decreased during storage. No significant changes were observed in the overall fatty acid profile, except for an increase in branched-chain fatty acids ($P < 0.05$). During storage, untreated milk showed a tendency towards an increase in saturated fatty acids and a decrease in polyunsaturated fatty acids, whereas treated samples remained more stable. High-pressure processing also affected technological properties. Rennet coagulation time (RCT) was significantly influenced by pressure level ($P < 0.05$), with higher pressures tending to prolong coagulation time while improving curd firmness and structural stability. Overall, high-pressure processing, particularly in the range of 300–400 MPa, improved microbiological quality and stabilised physicochemical properties of goat milk while maintaining its technological suitability for dairy procesing.

Keywords: *goat milk, high-pressure processing, microbiology, rennet coagulation, storage stability, physicochemical properties*

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NEW FAT REPLACEMENT FROM MILK PROTEIN

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Abstract

Our objective was to evaluate the use of milk fat globule membrane (MFGM) concentrate (Arla Foods Ingredients, Viby, Denmark) for production of a fat replacement. For this purpose we used microcoagulation process. The pH of protein dispersion had been adjusted to 3.50 and shear forces were applied simultaneously with heating. We examined the differences in physical properties of obtained microcoagulates in comparison to native pH of protein dispersion (6.16). At pH 3.5 aggregation was probably restricted due to electrostatic repulsions of positively charged protein molecules.

Transmission electron micrographs showed, that at pH 3.5, microcoagulates are composed of small particles. Organoleptically it mimicked fat texture. Microcoagulate obtained at pH 3.5 had better rheological properties (harder, more adhesive, more elastic) in comparison to pH 6.16. Viscosity of obtained microcoagulate at pH 3.5 was similar to viscosity of butter. This product can be used as fat replacement with high nutritional value, as it contains proteins with high content of essential amino acids and high content of phospholipids.

Keywords: *milk protein, microcoagulate, fat replacement, texture, surface*

IMPACT OF PLANT-DERIVED EXTRACTS ON QUALITY ATTRIBUTES, VOLATILE COMPOUND PROFILE, AND SENSORY CHARACTERISTICS OF YOGURT

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Abstract

Functional dairy products enriched with plant-derived ingredients are increasingly attracting interest due to their potential health benefits and improved sensory properties. The aim of this study was to evaluate the influence of selected herbal extracts on the physicochemical, sensory, and volatile compound profiles of stirred yogurts and to determine whether volatile compound profiling can be used to differentiate these products. Natural yogurts were supplemented with selected herbal extracts, including green tea, oregano, thyme, rosemary, and a commercial herbal blend, while plain yogurt served as the control. The products were manufactured under laboratory conditions and stored under refrigerated conditions. During storage, physicochemical parameters, colour, sensory attributes, and volatile compounds were analysed using headspace solid-phase microextraction coupled with gas chromatography–mass spectrometry (HS-SPME/GC-MS). Multivariate statistical analysis was applied to evaluate similarities and differences among yogurt variants. The addition of herbal extracts had only a minor effect on the basic chemical composition of yogurts but significantly influenced their aroma profile and sensory characteristics. Distinct differences in volatile compounds enabled clear discrimination of yogurts enriched with different herbal extracts. Among the tested formulations, yogurts containing oregano and thyme extracts exhibited the most pronounced modifications in aroma composition while maintaining favourable sensory acceptance. The results demonstrate that volatile compound profiling is an effective analytical approach for differentiating functional yogurts enriched with herbal extracts and may support the development, authentication, and quality assessment of innovative fermented dairy products.

Keywords: *functional yogurt, herbal extracts, volatile compounds, HS-SPME/GC-MS, sensory analysis, aroma profile, dairy products*

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THE EFFECT OF THE ADDITION OF PROTECTIVE *LACTOBACILLUS ACIDOPHILUS* LA-5® CULTURES ON THE GROWTH OF THE PATHOGENIC STRAIN *LISTERIA MONOCYTOGENES* IN BUTTERMILK ENRICHED WITH RETENTATE AFTER MICROFILTRATION

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Abstract

The aim of this study was to evaluate the effect of adding the protective culture Lactobacillus acidophilus LA-5® on the growth of the pathogenic strain Listeria monocytogenes in fermented buttermilk enriched with retentate obtained after microfiltration.

The buttermilk used as the test material was produced at the Department of Dairy Science and Quality Management and was then standardized to 5% protein content using retentate obtained after microfiltration of buttermilk, characterized by low fat content (2%) and high protein content (7.55%). Mesophilic lactic streptococci Flora Danica (Novonesis) were used for fermentation. The experimental products were intentionally contaminated with Listeria monocytogenes (inoculum 10^6 CFU/mL) and then incubated at temperatures of 5°C, 10°C, and 15°C. Microbiological and physicochemical analyses were performed immediately after production and after 1, 7, and 21 days of storage. To biocontrol the growth of the pathogen, the probiotic strain Lactobacillus acidophilus LA-5® was added to selected samples.

The conducted studies showed that fermented buttermilk enriched with microfiltration retentate provides a favorable environment for the growth of Listeria monocytogenes. At the same time, the validity of using Lactobacillus acidophilus LA-5® protective cultures as a potential tool to limit the growth of this pathogen in fermented buttermilk was confirmed, which underscores the need for further research on effective biocontrol methods in such products.

Keywords: *biocontrol*. *pathogen*, *Listeria monocytogenes*, *Lactobacillus acidophilus LA-5 ®*, *fermented buttermilk, probiotic, retentate*

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BIOCONTROL OF *LISTERIA MONOCYTOGENES* GROWTH IN YOGURT ENRICHED WITH BUTTERMILK MICROFILTRATION RETENTATE AND THE PROBIOTIC STRAIN *LACTOBACILLUS ACIDOPHILUS* LA-5 ®

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Abstract

The aim of the study was to evaluate the effectiveness of biocontrol in inhibiting the growth of Listeria monocytogenes in yogurt enriched with retentate obtained after microfiltration of buttermilk and the probiotic strain Lactobacillus acidophilus LA-5®. Listeria monocytogenes is one of the most dangerous foodborne pathogens, and its presence in dairy products poses a significant threat to consumer health, which justifies the search for effective methods to limit its growth in such products.

The test material consisted of natural yogurts produced under laboratory conditions, acidified with standard yogurt bacterial cultures and enriched with buttermilk microfiltration retentate. Some of the samples also contained the probiotic strain Lactobacillus acidophilus LA-5®. The yogurts were then divided into two groups: one was intentionally contaminated with L. monocytogenes to assess the ability of the bacterial cultures used to inhibit the growth and survival of the pathogen, while the other group served as a control.

Microbiological analyses were performed immediately after production and after 1, 4, 7, and 21 days of yogurt storage at temperatures of 5, 10, and 15°C. The results showed that the presence of yogurt bacteria in combination with the probiotic strain Lactobacillus acidophilus LA-5® effectively inhibited the growth of Listeria monocytogenes, with a marked reduction in pathogen growth observed as early as 7 days after storage.

Keywords: *pathogen, retentate*, *Listeria monocytogenes*, *Lactobacillus acidophilus LA-5 ®*, *yogurt*

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BIOACCUMULATION OF PERSISTENT ORGANIC POLLUTANTS IN MILK OF DIFFERENT ANIMAL SPECIES AS A CRITERION FOR QUALITY ASSESSMENT

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Abstract

Persistent organic pollutants (POPs) pose a significant threat to food safety due to their high chemical stability, lipophilicity, and ability to bioaccumulate and biomagnify within the food chain. Milk and dairy products, as important components of the human diet, may constitute a relevant source of consumer exposure to these compounds.

The aim of the study was to assess the level of bioaccumulation of selected POPs in retail milk from different animal species (cow, goat, sheep, mare) and to evaluate their significance in the context of product health quality assessment. Determinations were carried out using gas chromatography coupled with mass spectrometry (GC–MS), analyzing samples with varying fat content.

The analyses revealed species-dependent differences in the levels of the investigated compounds. The highest total concentrations of the analyzed POPs were found in sheep milk, which may be associated with its higher fat content. Lower levels were observed in goat milk, while the lowest concentrations were detected in cow milk, particularly in reduced-fat variants. The results confirm the relationship between lipid fraction content and the accumulation of hydrophobic contaminants.

The observed interspecies differences indicate that milk may serve as a sensitive indicator of the presence of persistent organic pollutants in the environment, and that monitoring their levels constitutes an important element of a comprehensive assessment of the quality and safety of dairy products.

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TRACE ELEMENT LEVELS IN VARIOUS TYPES OF MILK FROM THE NORTH-EASTERN POLISH MARKET

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Abstract

Milk is widely used in human nutrition, and its physicochemical properties make it an excellent raw material for processing. Milk is a source of valuable nutrients; it contains high-quality protein, as well as numerous vitamins, minerals, and trace elements In Poland, consumers most often consume cow's milk, but milk from other animal species is also available on the market. Consumers suffering from cow's milk protein allergy choose milk from other animal species, such as goat's milk, sheep's milk, and even mare's milk.

The aim of the study was to assess the trace element levels in various types of milk from the northeastern Polish market. The study included retail milk from various animal species (cows, goats, sheep, and mares). The study material was milk obtained from the northeastern Polish market. The milk was purchased from large supermarkets in the voivodeship capital. A total of 42 milk samples were analyzed, including cows (n=11), goats (n=11), sheep (n=10), and mares (n=10). The content of minerals (Fe, Zn, Cu, Mn) was determined by flame atomic absorption spectrometry (flame:acetylene:air) using an iCE 3000 Series atomic absorption spectrometer.

Species differences in the levels of the compounds studied were demonstrated. Sheep milk was characterized by a higher trace element content compared to other types of milk and is a rich source of iron, zinc, copper, and manganese in the human diet. Mare's milk had the lowest content of the analyzed elements. Therefore, it can be used for infant nutrition, as it does not overload their sensitive digestive systems.

Keywords: *goat's milk, sheep's milk, mare's milk, cow's milk, zinc, copper, manganese, iron*

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A REVIEW: APPLICATION OF PLANT PHENOLICS IN MEAT PRODUCTS

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Abstract

The global meat industry has recently shifted toward enhancing health benefits and reducing harmful ingredients. Plant polyphenols, known for their antioxidant and antimicrobial properties, are becoming key in formulating functional foods. The focus on using plant phenolics in meat systems is on controlling oxidized compounds and preserving meat by inhibiting microbial activity and oxidation, thereby minimizing synthetic additives. This concise review initially focuses on the antioxidant and antimicrobial roles of phenolics in meat products and then underscores the impact of covalent and non-covalent interactions between phenolics and meat matrix components on structure, functionality, physical, and chemical properties of meat, as well as the bioaccessibility and bioavailability of phenolics. The study reveals that the characteristics of different polyphenols used in meat products, including their reducing properties and gel-forming abilities, remain unclear, highlighting the need for advanced direct analytical methods in addition to the mostly used indirect analytical methods, such as gel electrophoresis, spectrophotometric, and colorimetric assays. The present work also aims to review advances in applying encapsulated phenolics in meat products to improve the stability and bioavailability of polyphenols while masking their undesirable flavors and odors. Overall, the results reveal that encapsulated polyphenols from various plant sources, such as mulberry, bay leaf, rosemary, garlic, thyme oil, and tea leaf, have the potential to preserve fresh and processed meat products through antibacterial and antioxidant activities while improving their quality attributes.

Keywords: *Antimicrobials, Antioxidants, Encapsulation, Meat preservation, Phenolics*

INFLUENCE OF PLANT-DERIVED BIOACTIVE COMPOUNDS ON MYOFIBRILLAR PROTEINS: PHYSICOCHEMICAL AND FUNCTIONAL MODIFICATIONS

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Abstract

The growing demand for clean-label solutions in meat processing has increased interest in plant-derived bioactive compounds as natural modifiers of protein functionality. This study examines how such compounds influence the physicochemical and functional properties of chicken breast myofibrillar proteins, with particular emphasis on raw material affected by quality defects.

Myofibrillar protein systems were combined with selected plant-derived compounds and analysed using thermal, spectroscopic, rheological and microstructural techniques. The results show that these compounds interact with proteins mainly through non-covalent interactions and oxidative pathways, leading to noticeable changes in protein structure and behaviour during heating and gelation.

The presence of plant-derived compounds improved thermal stability and promoted the formation of stronger, more cohesive protein gels. Changes in water-holding capacity and texture were also observed, depending on the concentration and composition of the added compounds. Microstructural analysis confirmed the development of more compact and homogeneous gel networks.

These results indicate that plant-derived bioactive compounds can be effectively used to modulate the functionality of myofibrillar proteins. This approach offers a practical strategy for improving the technological quality of poultry meat products, particularly when using raw materials with reduced functional properties.

Keywords: *protein, polyphenol, triterpenes, glycosides, plant-extracts*

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SALMONELLA spp. IN BROILER CHICKEN CARCASSES IN SOUTHERN POLAND: A SIX-YEAR MONITORING STUDY

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Abstract

Salmonellosis is the second most commonly reported foodborne disease in humans in the European Union. Despite the implementation of national programs to control selected Salmonella serovars in poultry, as well as process hygiene criteria established by food law, broiler meat remains one of the main food vehicles of Salmonella spp. transmission. The aim of the study was to determine the prevalence of Salmonella spp. in broiler chicken carcasses in abattoirs located in the Lesser Poland Voivodeship in southern Poland. The study materials comprised a total of 2,120 neck skin samples collected from broiler chickens during 424 slaughter processes in 14 processing plants from 2019 to 2024. Sampling was performed in accordance with Commission Regulation (EC) No 2073/2005, while Salmonella spp. detection and serotyping were conducted according to PN-EN ISO 6579-1:2017-04. Salmonella spp. were detected in 365 (17.2%) samples collected during 98 slaughter processes in 14 processing plants (14/14). The percentage of positive samples ranged from 6.3% in 2019 to 26.6% in 2022. Among the nine identified serovars, S. Infantis was the most prevalent (194 isolates, 53.1%), followed by S. Indiana (63, 17.3%), S. Newport (59, 16.2%), S. Enteritidis (38, 10.4%), S. Bardo (6, 1.6%), S. Senftenberg (2, 0.5%), along with S. Kentucky, S. Bovismorbificans, and Salmonella group O:4;y;- (1 isolate each, 0.3%). Broiler chicken carcasses can harbor Salmonella serovars that are not covered by food safety criteria, thereby posing a potential threat to public health. Improving slaughter hygiene, reviewing process control measures, ensuring the traceability of slaughtered animals, and implementing robust biosecurity practices on farms of origin are key to effectively reducing Salmonella spp. transmission.

Keywords: *Salmonella, Salmonella serovars, broiler chicken*

THE EFFECT OF HIGH-PRESSURE PROCESSING ON THE PHYSICOCHEMICAL AND MICROBIOLOGICAL QUALITY OF SUSHI DURING COLD STORAGE

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Abstract

Microbial spoilage is one of the primary causes of quality deterioration in ready-to-eat sushi products. Our previous studies demonstrated that although high-pressure processing (HPP) at pressures of 450 and 600 MPa effectively reduces the native microbiota of salmon sushi, it also negatively impacts key quality attributes, including color and texture.

*The present study investigated the potential of mild HPP (300 MPa for 2 and 4 min) applied to two types of sushi: Coho salmon (*Oncorhynchus kisutch*) nigiri and Coho salmon–avocado maki. The effectiveness of the treatment was evaluated in comparison with two control conditions: untreated sushi stored either under vacuum or air packaging. Changes in total viable counts, yeast and mould counts, texture (cutting strength and texture profile analysis), color (CIE Lab*), and pH were monitored during storage at 2°C.*

The results showed that both control groups exhibited a gradual increase in the microbial load up to day 20 of storage, followed by a rapid rise in yeast counts and total viable counts, which exceeded 6 log CFU/g by day 26. In contrast, HPP-treated samples remained microbiologically stable throughout the storage period. No yeasts or moulds were detected, and the total viable counts remained at 1.4–3.0 log CFU/g in samples treated at 300 MPa for 2 min, and below 1 log CFU/g in samples treated for 4 min. These levels remained unchanged even after 37 days of storage, when the experiment ended. However, HPP treatment also caused significant alterations in color intensity and texture, negatively affecting the sensory quality of the final product.

HPP appears to be a promising method for extending the shelf life of sushi products; however, further research is required to minimize its impact on sensory attributes.

Keywords: *High pressure processing, sushi, storage, shelf-life, non-thermal preservation*

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DEVELOPMENT OF A SCREENING METHOD FOR THE DETERMINATION OF IBUPROFEN AND ITS METABOLITES IN FISH MUSCLE TISSUE USING HPLC-DAD

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Abstract

Non-steroidal anti-inflammatory drugs (NSAIDs), classified as emerging contaminants, are ubiquitous in surface waters worldwide. Ibuprofen is one of the most frequently detected NSAIDs in aquatic environments and has been identified as a compound posing a significant ecotoxicological risk to aquatic organisms. It may also indirectly constitute a potential secondary source of human exposure. Monitoring the presence of these compounds requires the development of analytical methods enabling rapid and reliable detection of pharmaceuticals in biological samples. The aim of this study was to develop a screening method for the determination of ibuprofen and its metabolites – carboxyibuprofen, 1-hydroxyibuprofen, and 2-hydroxyibuprofen – in fish muscle tissue, using roach, based on high-performance liquid chromatography with diode-array detection (HPLC-DAD) in a reversed-phase mode. Sample preparation was performed using the QuEChERS extraction method. The method conditions were optimized to enable rapid analysis while maintaining high selectivity and adequate resolution (R_s>1.8), ensuring reliable monitoring of ibuprofen residues without significant interference. The recovery rates for fortified samples ranged from 75% to 91%. The developed method shows good linearity (R^2>0.9990 for all analytes), while limits of detection and quantification ranged from 0.007 to 0.011 µg/g and 0.023 to 0.036 µg/g, respectively. The proposed validated procedure represents a rapid, reproducible, and cost-effective screening tool that can reduce the number of analyses requiring more advanced instrumental techniques. However, due to the limited sensitivity of the method, positive or questionable results should be confirmed using mass spectrometry-based techniques. This study proposes a novel application of HPLC-DAD as a screening tool for the simultaneous determination of ibuprofen and its metabolites in fish muscle tissue. It addresses the growing need for accessible analytical methods for monitoring pharmaceutical residues in food and assessing consumer risk.

Keywords: *HPLC-DAD, ibuprofen metabolites, emerging contaminants, screening analysis, fish muscle tissue, food safety*

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FEASIBILITY OF SIMULTANEOUS CADMIUM AND LEAD DETERMINATION IN FRUIT JUICES BY DIRECT SAMPLING GFAAS

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Abstract

Commercial fruit juices are widely consumed by all age groups. This can contribute to dietary exposure to toxic trace elements. The current study introduces a rapid and sustainable method to determine Cd and Pb simultaneously in commercial fruit juices using direct sampling graphite furnace atomic absorption spectrometry (GFAAS). This method does not involve any sample pretreatment technique. It employs appropriate types and optimized masses of chemical modifiers (5 µg Pd and 0.5 µg Mg, as nitrates), oxidizing agents (10% HNO_3 and 60% H_2O_2), diluents, and an optimized graphite furnace heating program to ensure effective matrix removal and thermal stabilization of the analyte. Method performance was evaluated in terms of linearity, sensitivity, accuracy, and precision. Excellent linearity was obtained for both analytes up to concentrations of 5 µg/L Cd and 100 µg/L Pb. LOD and LOQ values were below the regulatory limits. Method accuracy was verified using spiked samples and a certified reference material (TMDA-51), for which satisfactory recovery (103.3% and 94.4%) and repeatability (0.3% and 3.1% at 3.61 µg/L and 66.6 µg/L) were obtained for Cd and Pb, respectively. The developed method was applied to 32 fruit juice samples. Dietary exposure and health risk assessment were conducted based on the European Food Safety Authority. Estimated daily intake and target hazard quotient were calculated for Cd. Pb risk was characterized by using margin of exposure. The results indicate that Cd and Pb concentrations in the analyzed fruit juices do not pose a significant health concern. The developed method provides a reliable, cost-effective, and environmentally friendly alternative for Cd and Pb determination in fruit juices to support food safety assessment and regulatory compliance.

Keywords: *Direct sample analysis, ETAAS, graphite furnace atomic absorption spectrometry, nonalcoholic beverage, trace element analysis, health risk assessment*

PHOTODYNAMIC AND SONODYNAMIC ANTIBACTERIAL ACTIVITY OF GRAPE LEAF EXTRACTS FOR FOOD PRESERVATION APPLICATIONS

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Abstract

Food spoilage caused by microbial contamination remains a major challenge for the food industry, resulting in reduced product quality, shortened shelf life, and significant economic losses. The development of natural antimicrobial agents derived from agricultural by-products represents a sustainable strategy for improving food preservation while reducing reliance on synthetic additives.

In this study, grape leaves obtained from Beer and Hanut Orcha grape varieties were investigated as sources of natural antimicrobial compounds. Crude extracts were prepared and evaluated against the food-related bacterial contaminants Staphylococcus aureus and Escherichia coli under photodynamic (light-assisted) and sonodynamic (ultrasound-assisted) activation. The influence of extract concentration and treatment duration on antibacterial efficacy was examined. In addition, chromatographic fractionation was employed to isolate active components responsible for the observed antimicrobial effects.

Both photodynamic and sonodynamic treatments significantly enhanced the antibacterial activity of the grape leaf extracts. Complete eradication of S. aureus and E. coli was achieved under optimized activation conditions. Fractionation of the extracts yielded a highly active fraction with enhanced antibacterial efficacy. Measurements of singlet oxygen generation confirmed the involvement of reactive oxygen species in bacterial inactivation.

The results demonstrate that grape leaves, an underutilized agricultural by-product, can serve as a valuable source of natural antimicrobial agents. The combination of plant-derived extracts with light or ultrasound activation offers a promising approach for food preservation, surface decontamination, and the development of sustainable technologies for improving food safety and shelf life.

Keywords: *food preservation, grape leaves, agricultural by-products, natural antimicrobials, photodynamic treatment, sonodynamic treatment, food safety.*

Acknowledgments: *We gratefully acknowledge the Research Authority of Ariel University, Ariel, Israel, for supporting this research.*

RECOVERY OF PHENOLIC COMPOUNDS FROM PEAR POMACE THROUGH ULTRASOUND-ASSISTED EXTRACTION: OPTIMIZATION, PHENOLIC PROFILE AND ANTIOXIDANT ACTIVITY

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Abstract

Pear pomace is a major by-product of the juice processing industry and represents a rich source of bioactive compounds; however, its potential as a valuable resource remains largely underutilized. In this study, ultrasound-assisted extraction (UAE) was evaluated using Response Surface Methodology (RSM) to optimize the extraction of phenolic compounds from pear pomace powder with aqueous ethanol as the solvent. For this purpose, an optimization study was carried out using a Box-Behnken factorial design to assess the effect of ethanol concentration (40-80%), extraction time (30-90 min) and ultrasonic power intensity (48-144 W) on total phenolic content and DPPH radical scavenging activity as response variables. The experimental data were fitted to second-order polynomial models using multiple regression analysis and further evaluated using appropriate statistical methods. Additionally, the phenolic composition of the extracts was analyzed by high-performance liquid chromatography. According to the model, the maximum DPPH radical scavenging activity (0.93 mmol Trolox/L) was predicted at an ethanol concentration of 40%, an extraction time of 56.51 minutes, and a power intensity of 116.64 W. Extraction using 40% ethanol for 64.45 minutes at a power intensity of 117.6 W resulted in the highest recovery of phenolic compounds, yielding 280.1 mg GAE/L in the extracts. The R-squared values for the two models were 91.27% and 95.59%, respectively. According to the HPLC analysis, chlorogenic acid, caffeic acid, rutin, and epicatechin were identified as the major polyphenolic compounds in the extracts. The results demonstrated the considerable potential of pear pomace as an economical source of bioactive compounds and the optimized UAE method proved to be an effective and versatile strategy for maximizing the recovery of bioactive compounds from pear pomace.

Keywords: *pear by-products; ultrasound-assisted extraction; optimization; phenolic compounds; antioxidant activity; process parameters*

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CONVECTIVE DRYING KINETICS AND MATHEMATICAL MODELING OF WILLIAMS PEAR POMACE FOR SUSTAINABLE VALORIZATION

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Abstract

Pear pomace, a major by-product from juice processing, represents a significant waste stream in the fruit industry, yet offers substantial potential for valorization within circular economy frameworks. Being rich in valuable bioactive compounds, including dietary fiber, polyphenols, and antioxidants, by drying, pear pomace can be valorized and suitable for various applications in functional food formulations, food supplements, and animal feed. Optimization of drying parameters allows the preservation of nutritional quality, while ensuring microbiological stability and an extended shelf life.

This study investigates forced convection drying as a cost-effective preservation method to transform Williams variety pear pomace into value-added products while reducing environmental impact.

Convective drying experiments were conducted at three temperatures (60, 65, and 70°C) to optimize process parameters and evaluate their impact on drying kinetics and physicochemical properties. Results demonstrated that temperature significantly influenced moisture removal efficiency, with 70°C achieving complete drying in 90 minutes compared to 105 minutes at 60°C. Peak drying rates ranged from 0.0145 to 0.0185 (g water/dry matter)/min, increasing proportionally with temperature. Mathematical modeling using Fick's second law revealed effective moisture diffusivity values of 1.62-1.88 × 10^{-9} m^2/s, with excellent model fit ($R^2 > 0.92$). The calculated activation energy of 14.2 kJ/mol indicates favorable energy requirements for industrial-scale implementation.

This research contributes to sustainable waste management strategies in the fruit processing sector by providing comprehensive kinetic data and validated mathematical models for industrial dryer design. The findings support the technical and economic feasibility of pear pomace valorization, promoting circular economy principles and reducing the environmental footprint of juice production operations.

Keywords: *pear pomace, drying, forced convection, drying kinetics, circular economy, valorization, waste reduction*

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CHARACTERISTICS AND NUTRITIONAL POTENTIAL OF VARIOUS FRUIT POMACE MATERIALS

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Abstract

The dynamic growth of the agri-food industry generates substantial quantities of by-products, such as fruit pomace, which pose environmental and economic challenges and require effective management within the framework of a circular economy. The aim of this study was to evaluate and compare the functional, nutritional, and physicochemical properties of dried pomace obtained from apple (A), chokeberry (C), grape (G), raspberry (R), and red currant (RC) and to assess their potential as functional ingredients in food products. The analyses revealed that all investigated pomaces were rich sources of dietary fibre, with total dietary fibre content ranging from 37.45% to 67.38% d.w. Red currant pomace was characterized by the highest levels of protein (13.01% d.w.), fat (6.82% d.w.), and total dietary fibre. Mineral analysis confirmed high concentrations of potassium, phosphorus, and calcium in all samples, while grape and red currant pomaces exhibited the highest overall mineral content. Significant differences were observed in the functional properties of the analysed materials. Titratable acidity ranged from 1.41 to 7.96 g·100 g^{-1} d.w. Water-holding capacity (WHC) varied between 2.36 and 4.25 g·g^{-1}, with apple pomace exhibiting the highest value. Oil-holding capacity (OHC) ranged from 1.86 to 2.41 g·g^{-1}, with grape pomace demonstrating the highest capacity. Colour analysis showed that apple pomace was the lightest material (L = 66.29), whereas red currant and raspberry pomaces exhibited the highest redness values (a*). The results confirm that fruit pomace is a valuable secondary raw material with considerable nutritional and technological potential. The utilisation of these by-products as functional ingredients may improve the nutritional quality of food products while supporting circular economy and waste reduction strategies.*

Keywords: *fruit pomace, dietary fibre, functional properties, colour parameters, minerals, sustainable food systems*

EFFECT OF DRYING CONDITIONS ON THE ANTIOXIDANT ACTIVITY OF STRAWBERRY POMACE POWDERS AND THEIR APPLICATION IN COOKIES

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Abstract

Strawberry pomace is a by-product of fruit processing and a potential source of antioxidant compounds suitable for use as functional food ingredients. The aim of this study was to evaluate the effect of different drying conditions on the antioxidant activity of strawberry pomace powders and cookies enriched with these powders, as well as to assess changes in antioxidant potential following simulated gastrointestinal digestion. Dried strawberry pomace powders obtained by freeze-drying and contact drying under different temperature conditions, along with enriched cookies, were subjected to an in vitro digestion model simulating oral, gastric, and intestinal phases. Antioxidant activity was evaluated using ABTS and DPPH radical scavenging assays and the FRAP method, and the results were compared for non-digested and digested samples. Strawberry pomace powders exhibited markedly higher antioxidant activity before digestion than after simulated digestion across all applied assays. Prior to digestion, freeze-dried pomace powders showed higher antioxidant activity compared to contact-dried samples; however, this effect was not consistently observed after digestion. Cookies enriched with freeze-dried pomace generally demonstrated higher antioxidant activity than those enriched with contact-dried pomace. In the case of ABTS and DPPH assays, an increase in antioxidant activity of enriched cookies was observed with increasing contact-drying temperature of the pomace, both before and after digestion. These results indicate that both drying method and digestion significantly influence the antioxidant potential of strawberry pomace powders and enriched food products, highlighting the importance of processing conditions when assessing their functional properties.

Keywords: *fruit by-products, phenolic compounds, thermal processing, bioaccessibility, baked products, simulated digestion*

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CHANGES IN COLOR, TEXTURE AND SENSORY CHARACTERISTICS OF GLUTEN-FREE BREAD FORTIFIED WITH CHOKEBERRY POMACE

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Abstract

The aim of this study was to assess the effect of adding convectively dried and freeze-dried chokeberry pomace on the color, texture, and sensory properties of gluten-free bread. The research involved fortifying bread with 5% and 10% additions of these fruit residues. Instrumental analysis of the crumb color in the CIELab space showed that the addition of chokeberry pomace significantly decreased lightness (L) and increased redness (a*), making the bread darker and more red compared to the control sample. Textural analysis (TPA test) conducted 4 and 24 hours after baking revealed that the introduction of 5% chokeberry pomace generally led to a decrease in crumb hardness and chewiness, while not significantly affecting elasticity and cohesiveness. Sensory evaluation performed by consumers indicated that gluten-free breads enriched with chokeberry pomace were well-accepted. The highest average scores were obtained by samples with a 5% addition of convection-dried chokeberry pomace, which is recommended due to its optimal balance of elasticity and low hardness. The study concludes that chokeberry pomace is a valuable functional ingredient that supports sustainable development by utilizing food industry by-products to improve the quality of gluten-free bakery products*.

Keywords: *gluten-free bread, chokeberry pomace, color, texture, sensory evaluation*

COMPARATIVE STUDY OF NATURAL AND REFINED SALT ON THE COLOR PARAMETERS AND SENSORY QUALITY OF WHEAT BREAD

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Abstract

Reducing sodium intake represents one of the most pressing global nutritional challenges. Reformulating bread recipes to lower sodium content has therefore become an important priority in order to maintain desirable sensory characteristics. Unlike refined salt (RS), which is commonly used in baking, natural salt extracted from the Atacama Desert (SS) is characterized by a unique crystalline structure in which each granule contains both sodium chloride and potassium chloride. The aim of this study was to evaluate the effect of different concentrations of RS and SS (0.4%, 0.8%, 1.2%, and 1.6%) on the CIELab color parameters of the crumb of bread produced from high-quality wheat flour. The CIELab color parameters were measured using a Konica Minolta CR-400 colorimeter (Tokyo, Japan). The following parameters were recorded: L (lightness), a* (red–green parameters), and b* (yellow–blue parameters). The sensory quality of the bread samples (appearance, taste, color, odor, texture, and aroma) was evaluated using a nine-point hedonic scale. Sensory analysis indicated that all breads prepared with SS were perceived as more pleasant than those prepared with RS, possibly due to the presence of natural minerals (magnesium, calcium, and potassium), which enhanced aroma and taste. The crumb color of both SS and RS bread samples ranged from creamy white to light cream. As the salt concentration increased, the L* values increased, indicating a lighter crumb color. The a* values were negative, indicating a slight green hue, while the b* values were positive, indicating a yellow hue. These color characteristics may be attributed to the quality of wheat flour, dough aeration during kneading, and the porous crumb structure, which enhances light reflection. The results suggest that SS may be used to produce healthier bakery products without compromising quality.*

Keywords: *natural salt; color parameters; sensory quality; bread*

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INFLUENCE OF THE ADDITION OF SOURDOUGH FROM RYE FLOUR ON THE PROPERTIES OF SALT-FREE DOUGH AND BREAD

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Abstract

The dough preparation method plays a crucial role in determining the quality characteristics of bread. The use of sourdough has been widely recognized for improving the sensory, physicochemical, and textural properties of bakery products and is considered a promising strategy for mitigating the negative effects associated with salt reduction or complete salt omission. This study investigated the influence of rye flour sourdough on the rheological properties of dough and the quality characteristics of salt-free wheat bread. Dry rye sourdough Sapore Traviata was incorporated into the dough at levels of 1, 2, 3, and 4% (flour basis). Dough behavior during mixing and fermentation was evaluated using a Mixolab and a Rheofermentometer. The addition of sourdough had only a minor effect on dough development time, which averaged 1.43 ± 0.22 min, while dough stability increased with increasing sourdough concentration, reaching an improvement of 3.4 min at the highest addition level compared with the control. This effect is likely related to changes in the gluten network promoted by sourdough components. Furthermore, sourdough enhanced both the production and retention of fermentation gases. Five salt-free bread samples were prepared using wheat flour and 3% dry baker's yeast. Bread quality was evaluated by determining crumb porosity, crumb color using a Konica Minolta CR-400 colorimeter, textural properties using a TA.HD plus C texture analyzer and sensory acceptance using a nine-point hedonic scale. The incorporation of sourdough resulted in only a slight decrease in crumb porosity (approximately 1%), with an average value of 71%. Increasing sourdough levels produced a darker crumb and significantly increased crumb hardness and chewiness. However, breads containing sourdough received higher sensory scores for aroma and taste than the control sample. These findings suggest that rye sourdough is a suitable ingredient for improving the sensory quality of salt-free bread.

Keywords: *salt-free bread; sourdough; quality parameters*

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EFFECT OF DAIRY-BASED RECIPE MODIFICATION OF CLASSIC BAKERY PRODUCTS ON ESTIMATED GLYCAEMIC INDEX, NUTRITIONAL COMPOSITION AND CONSUMER ACCEPTANCE

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Abstract

Traditional bakery products are generally characterised by a high energy density, a considerable content of available carbohydrates and an unfavourable glycaemic profile. Recipe reformulation using dairy products rich in protein may improve their nutritional value; however, maintaining desirable sensory properties remains an important technological challenge. The aim of this study was to evaluate the effect of recipe modification of selected classic bakery products on their nutritional composition, estimated glycaemic index and consumer acceptance. Traditional wuzetka cake and cheesecake were used as model products. Their recipes were modified by incorporating high-protein dairy ingredients, including skyr, and by partially replacing selected conventional ingredients. The developed variants were compared with traditional control products. Protein, dietary fibre, dry matter and ash contents were determined, while carbohydrate content and energy value were calculated. The estimated glycaemic index and glycaemic load were determined indirectly based on the carbohydrate composition of the products. Consumer acceptance was assessed using a nine-point hedonic scale. Recipe modification resulted in considerable differences in the nutritional characteristics of the products. In the cheesecake study, the skyr-based variant had the lowest energy value, amounting to 242.57 kcal/100 g, the lowest available carbohydrate content of 12.74 g/100 g and the highest dietary fibre content of 6.55 g/100 g. This variant also showed the lowest estimated glycaemic index and glycaemic load. The high-protein cheesecake contained 15.63 g of protein per 100 g. Modified wuzetka variants also demonstrated a more favourable estimated glycaemic profile than the traditional product, although the extent of recipe modification affected consumer acceptance. The results indicate that dairy-based reformulation may improve the nutritional and glycaemic characteristics of traditional bakery products. Nevertheless, comprehensive recipe optimisation is necessary to achieve a balance between nutritional benefits and consumer acceptance.

Keywords: *bakery products; recipe reformulation; dairy products; skyr; estimated glycaemic index; nutritional value; consumer acceptance*

Acknowledgments: *This research was funded within the project "Research Network of Universities of Life Sciences for the Development of the Polish Dairy Sector – Research Project" (SUP-RIM), financed by a targeted grant from the Minister of Science and Higher Education.*

FERMENTED BEETROOT AS A SOURCE OF BIOACTIVE COMPOUNDS: CHEMICAL COMPOSITION AND BIOLOGICAL ACTIVITY

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Abstract

Fermented plant-based foods are increasingly recognised as functional foods because fermentation generates a complex matrix of phytochemicals, microbial metabolites, and beneficial microorganisms with potential health-promoting properties. Beetroot (Beta vulgaris L.) is particularly rich in betalains, phenolic compounds, dietary nitrates, vitamins, minerals, and other antioxidants, making it an excellent substrate for the development of functional fermented foods.

The aim of this study was to evaluate fermented beetroot products as a source of bioactive compounds and determine their functional properties. Beetroot roots, leaves, and root–leaf combinations were subjected to spontaneous lactic acid fermentation. Changes in the chemical composition of fermented and non-fermented beetroot products were characterised using HPLC-MS fingerprinting, whereas biological activity was assessed based on antioxidant potential and the functional properties of isolated lactic acid bacteria (LAB).

HPLC-MS fingerprinting revealed distinct phytochemical profiles among fermented beetroot products. Leaf-containing samples were particularly rich in apigenin derivatives, including vitexin hexoside, vitexin xyloside, vitexin rhamnoside, and ferulic acid hexoside, whereas root-derived products contained betalain pigments such as betanin, isobetanin, vulgaxanthins, indicaxanthin, and neobetanin derivatives. These findings indicate that spontaneous fermentation contributes to diversification of the phytochemical profile while preserving biologically active pigments characteristic of beetroot. Fermented beetroot products were enriched with LAB belonging predominantly to the genera Weissella, Leuconostoc, and Lactiplantibacillus. Selected isolates exhibited beneficial properties, including adhesion-related characteristics, antimicrobial activity, and antioxidant potential.

The obtained results demonstrate that fermented beetroot represents a multifunctional food matrix combining plant-derived bioactive compounds with beneficial microbial activity. These findings support the development of fermented beetroot-based functional foods intended for health promotion and preventive nutrition.

Keywords: *fermented beetroot, functional food, HPLC-MS, betalains, phenolic compounds, lactic acid bacteria, antioxidant activity*

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SUSTAINABLE VALORISATION OF AGRICULTURAL AND FORESTRY RESIDUES THROUGH SHIITAKE MUSHROOM CULTIVATION

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Abstract

This study aligns with the principles of circular bioeconomy and sustainable bioprocessing by investigating the use of locally available agricultural and forestry residues as growth substrates for shiitake mushroom (Lentinula edodes). A total of 30 different substrate compositions—including hazelnut branches, acacia wood, oak sawdust, beech sawdust, corn cob, chestnut shell, straw, and oak gall—were systematically evaluated for their impact on fungal growth, yield, and morphological quality. The highest total fresh yield was obtained from the 50% acacia wood + 50% hazelnut branches mixture (250.8 g/kg), followed by 50% acacia wood + 50% corn cob (203.5 g/kg) and 100% hazelnut branches (189.6 g/kg). The earliest first harvest (≈60 days) was recorded on oak sawdust, chestnut shell, and beech sawdust. Beech sawdust produced the largest cap diameter (11.3 cm), while the longest stipe (4.9 cm) was achieved with the beech sawdust–acacia wood combination. Substrates containing oak gall resulted in significantly low yields (<40 g/kg), attributed to its high tannin content inhibiting mycelial development. These results demonstrate that regionally available lignocellulosic residues can be effectively valorised through mushroom cultivation. The identified substrate combinations offer a replicable model for biomass valorisation and sustainable bioprocessing.

Keywords: c*ircular bioeconomy, shiitake mushroom, lignocellulosic residues, sustainable bioprocessing*

PULSED ELECTRIC FIELD AND PLASMA APPLICATIONS FOR SELECTIVE TREATMENT OF ALGAL-BACTERIAL CO-CULTURES

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Abstract

The growing demand for sustainable algae-based products for food, feed, biofuel, and pharmaceutical applications is challenged by contamination in open cultivation systems. Harmful microorganisms, including protozoa, bacteria, and viruses, disrupt algal growth, reduce biomass productivity, and limit the commercial viability of algal cultivation. Conventional decontamination methods are often non-selective and may compromise algal viability and functionality.

This study presents a novel, selective, non-thermal strategy for microbial control based on pulsed electric fields (PEF) and plasma technologies (gliding arc discharge and spark arc discharge) in a co-culture system of Chlorella vulgaris and bacterial strains: Delftia spp. and Serratia spp. PEF enables targeted microbial inactivation by exploiting species-specific electroporation thresholds, while gliding arc discharge plasma and spark arc discharge were used to produce plasma-activated water (PAW) for providing effective oxidative decontamination. The combined approach modulates the microbial balance, suppresses harmful microorganisms, and enhances algal productivity while preserving algal functional properties.

The investigation focuses on the optimization of PEF and plasma treatment parameters for selective bacterial inactivation and evaluating the combined treatment in the co-culture system. Optimized treatment conditions enable selective microbial inactivation in nutrient-rich cultivation media, preserving algal cells while reducing undesirable bacterial populations. The results provide valuable insights into the application of selective non-thermal technologies in industrial algal biotechnology and establish fundamental principles for microbial engineering in complex algal cultivation systems, contributing to improved sustainability, product quality, and competitiveness in the European algae-based bioindustry.

Keywords: *Chlorella vulgaris, co-culture, plasma, pulsed electric field*

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THE RELATIONSHIP BETWEEN EATING HABITS AND THE CONSUMPTION OF SELECTED FOOD INGREDIENTS

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Abstract

Eating habits play a key role in shaping diet quality and influence the intake of nutrients essential for health. The aim of this study was to analyze the relationship between dietary patterns and the consumption of selected food groups, with particular emphasis on milk and dairy products as an important component of the diet.

The study focused on the analytical evaluation of food composition and the characterization of compounds present in milk and dairy products. The analysis included a general assessment of chemical composition and the identification of key protein and lipid fractions as well as bioactive components that may affect the nutritional value of dairy products and their role in dietary models. Standard analytical methods used in food quality research were applied, including chromatographic and spectrophotometric techniques as well as classical physicochemical determinations.

The results indicate that dietary patterns that include regular consumption of dairy products are associated with a more balanced dietary profile and higher overall diet quality. At the same time, variability in the composition of dairy products, resulting from technological processes and the degree of processing, may influence their nutritional function.

The study highlights the importance of combining the analysis of eating behaviors with objective food composition assessment, particularly in relation to milk and dairy products. The findings may provide a basis for further research on the role of dairy products in shaping diet quality and may support educational and nutritional strategies aimed at improving eating habits.

Keywords: *eating habits, diet quality, dairy products, bioactive compounds, dietary patterns*

Acknowledgments: *This study was supported by the Task entitled "The Research Network of Life Sciences Universities for the Development of the Polish Dairy Industry--Research Project" funded under the designated subsidy of the Minister of Science and Higher Education (MEiN2023/DPI/280).*

DIETARY INTAKE OF AGRICULTURAL PRODUCTS AND SERUM PFAS CONCENTRATIONS: A NATIONAL BIOMONITORING STUDY OF SOUTH KOREAN ADULTS

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Abstract

The main objective of this study was to investigate the association between the dietary intake of agricultural products and serum concentrations of perfluoroalkyl substances (PFAS) in South Korean adults. Data were obtained from a representative national sample of 5,000 individuals conducted by the Ministry of Food and Drug Safety between 2023 and 2025. The analysis focused on 1,848 men and 1,954 women aged 19 years and older. Dietary intake was assessed using 24-hour recall, and linear regression was performed to evaluate the relationship between food groups and serum levels of total PFAS, PFOA, and PFOS. Age was the most significant positive predictor of PFAS concentrations in both genders. Among dietary factors, vegetable intake showed a significant positive association with serum PFAS levels in both men and women ($p < 0.05$). In women, mushroom consumption was significantly associated with higher serum concentrations of total PFAS and PFOA. Conversely, egg consumption in men was associated with relatively lower levels of PFAS compared to other variables. These findings indicate that the consumption of specific agricultural products, particularly vegetables and mushrooms, represents a significant pathway for PFAS exposure in the general population. This study highlights the necessity for continuous monitoring and targeted risk management within the agricultural sector to ensure food safety and protect public health from persistent environmental pollutants.

Keywords: *PFAS, PFOA, PFOS, Dietary intake, Agricultural products, Biomonitoring, Food safety, South Korea*

Acknowledgments: *This research was supported by a grant (23194MFDS073) from the Ministry of Food and Drug Safety, Republic of Korea in 2023-2025. The authors thank all study participants and the field staff who contributed to data collection.*

BIOCHEMICAL AND METABOLIC EFFECTS OF SARDINE SUPPLEMENTATION IN AN EXPERIMENTAL ANIMAL MODEL

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Abstract

Sardines (Sardina pilchardus) are a rich source of biologically active compounds, including omega-3 fatty acids (EPA and DHA), high-quality protein, minerals and vitamins. These nutrients may contribute to the regulation of oxidative stress. The aim of this study was to evaluate the effects of dietary sardine supplementation on selected serum markers of oxidative stress in a rat model. The experiment was conducted using 48 male Wistar rats divided into four experimental groups (n = 12 per group): control - C, streptozotocin-treated - STZ, sardine-fed - SAR, and streptozotocin-treated rats receiving a sardine-enriched diet - STZ+SAR. The feeding trial lasted 8 weeks. Experimental diets were formulated based on the AIN-93G diet and balanced to provide comparable energy and macronutrient content. At the end of the experiment, serum samples were collected for the determination of total bilirubin, uric acid, malondialdehyde (MDA), and glutathione reductase (GR) with commercially available kits. Compared with the C group, STZ-treated rats exhibited higher serum bilirubin concentrations, whereas bilirubin levels in the serum of the STZ+SAR group were lower, additionally there was no differences between C-group and STZ+SAR group. Serum uric acid concentration was also elevated in the STZ group compared with the control group. In contrast, both SAR and STZ+SAR groups showed significantly lower uric acid concentration. Malondialdehyde (MDA), a marker of lipid peroxidation and oxidative stress, was significantly increased in the serum of STZ-treated rats compared to C-group. Sardine supplementation was associated with lower MDA concentrations, and values in the STZ+SAR group were comparable to those observed in the C- group. Glutathione reductase (GR) activity was significantly higher in the STZ group than in the control group, while significantly lower activity was observed in the STZ+SAR group. Overall, dietary sardine supplementation may reduce oxidative stress and improve selected biochemical parameters.

Keywords: *bioactive compounds, sardines, oxidative stress*

Acknowledgments: *The research was funded by the National Science Centre, Poland, UMO-2020/39/I/NZ9/02959.*

FOOD-RELATED STRATEGIES IN COLORECTAL CANCER MANAGEMENT: NUTRITIONAL PREHABILITATION, SUPPLEMENTATION AND ENVIRONMENTAL EXPOSURE

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Abstract

Physical rehabilitation and nutritional support are important but still underestimated elements of comprehensive therapy for patients with colorectal cancer. The inclusion of appropriately planned physical activity and dietary interventions as early as the prehabilitation stage improves physical condition, maintains muscle mass, reduces the frequency of complications and side effects of treatment, and has a positive impact on patient prognosis. This is particularly important in cancer patients, in whom malnutrition significantly limits therapeutic options and worsens treatment tolerance. The goal of nutritional rehabilitation is to optimize nutritional status before starting cancer treatment. It includes assessing the risk of malnutrition, modifying the diet, and targeted supplementation, including protein, immunonutrition, vitamins, and minerals. Proper supplementation can support the immune system, improve the regeneration process, and increase the effectiveness of treatment. In the context of the growing incidence of colorectal cancer, the issue of the impact of environmental pollutants on carcinogenesis processes has also been addressed. Pesticides, agricultural chemical residues, and numerous food additives can disrupt the gut microbiota, have pro-inflammatory effects, and promote the development of cancerous changes. The aim of this study is to show that the integration of physical rehabilitation, nutritional interventions, appropriately selected supplementation, and minimization of exposure to environmental pollutants creates a holistic model of care for patients with colorectal cancer. This multidimensional approach improves prognosis, quality of life, and treatment effectiveness, and its implementation should become standard in modern clinical practice.

Keywords: *colorectal cancer, nutritional prehabilitation, malnutrition, immunonutrition, environmental pollution*

CONSUMPTION OF ENERGY DRINKS AND ALCOHOL MIXED WITH ENERGY DRINKS AMONG POLISH ADOLESCENTS

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Abstract

Energy drinks (EDs) are extremely popular among young adults as well as adolescents. Regular intake of EDs may lead to an overdose of caffeine, overweight, dental erosion, dental caries, hypertension and, in later age, osteoporosis and cardiovascular diseases. Some people mix energy drinks with alcohol (AmEDs), which adversely affects their health and can lead to dangerous behavior. The objective of this study was to analyze the consumption of EDs and AmEds by adolescents.

The study consisted of a questionnaire in the context surveying of amounts of drinks, preferences and the awareness among younger consumers. The study was carried out in students in senior high schools in north Poland (n=390).

EDs were consumed by 66% of students (approximately 25% daily and several times a week). When selecting a particular ED, young people looked at the taste, next ingredients, price and availability. Most respondents (about 66%) knew the ingredients of energy drinks, correctly identifying caffeine, sugar or sweetener, and taurine. 36% of students admitted to mixing EDs with alcohol. More men than women consumed AmEDs (42.5% vs. 29%). Respectively, 11% and 7% of students experienced symptoms after consuming EDs and AmEDs. 11% and 7% of students, respectively, experienced symptoms after consuming ED and AmEDs, mainly arrhythmia, headache and abdominal pain.

Energy drinks are extremely popular among adolescents. The group of students drinking EDs every day is potentially at risk of taking an overdose of caffeine.

Keywords: *caffeine, students, alcohol, energy drinks, consumption*

HEALTH BENEFITS OF SELECTED BIOLOGICALLY ACTIVE COMPOUNDS IN *SALVIAE HERBA*

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Abstract

Plants of the genus Salvia have been used in traditional medicine for centuries. Currently, Salviae herba derived from many species, including Salvia officinalis, Salvia officinalis var. lavandulifolia, and Salvia sclarea, constitutes a valuable source of bioactive secondary metabolites exhibiting a broad spectrum of biological activities and is widely used in the pharmaceutical, cosmetic, and food industries. The aim of this study was to present the health-enhancing properties of active compounds contained in plants of the genus Salvia based on the current state of knowledge. Salvia officinalis exhibits antibacterial, anti-inflammatory, analgesic, and antioxidant activities owing its content of α-thujone, camphor, and 1,8-cineole. 1,8-Cineole reduces the production of pro-inflammatory cytokines and oxidative stress through the inhibition of NF-κB activation. Camphor and thujone modulate neuronal receptors and ion channels, thereby stimulating the central nervous system. In contrast, S. sclarea has sedative and anxiolytic effects, primarily due to the presence of linalool and linalyl acetate. Linalool modulates GABAA_AA and inhibits TRPA1 channels in sensory neurons, which reduces nervous system excitability and decreases the transmission of pain stimuli. Sclareol, a characteristic compound of this species, exhibits anti-inflammatory activity through inhibition of the NF-κB and MAPK signalling pathways and reduction of the expression of COX-2 and iNOS inflammatory mediators. In turn, S. officinalis var. lavandulifolia has neuroprotective and cognition-enhancing properties, mainly due to its content of 1,8-cineole and α-pinene. 1,8-Cineole inhibits acetylcholinesterase activity and increases acetylcholine availability in synapses, which may support memory and concentration. α-Pinene exerts anti-inflammatory and antioxidant effects through inhibition of the production of reactive oxygen species and inflammatory mediators. Salviae herba exhibits therapeutic potential; nevertheless, further studies are warranted to standardise the dosage and ensure the safety and efficacy of its use.

Keywords: *Salvia officinalis*, *Salvia officinalis* var. *lavandulifolia*, *Salvia sclarea*, *biologically active compounds, phytochemicals, phytotherapy*

A REVIEW OF AGRONOMIC AND ECONOMIC STRATEGIES FOR SMALL FARMS

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Abstract

Small farms represent an important segment of agriculture, with an essential role in food security, biodiversity maintenance and the socio-economic development of rural areas. The aim of this review paper was to analyse agronomic and economic strategies that can improve the performance of small farms, with emphasis on diversified crop structures adapted to local conditions. The methodology consisted of a narrative review with systematic elements, based on scientific literature and institutional reports published mainly during 2016-2026. Studies on crop diversification, crop rotations, grain and forage legumes, cover crops, intercropping, agroforestry, local marketing and economic cooperation were analysed. The results show that functional diversification and well-designed rotations can increase yield stability, improve soil health, reduce economic risks and strengthen agronomic resilience. However, economic effects are not uniform, because profitability depends on farm size, available resources, access to water, labour, machinery, markets and the organisation of marketing channels. For small farms, the most realistic solution is gradual diversification by combining a core of basic crops with legumes, higher value commercial crops and, where feasible, cover crops or associated systems. The paper concludes that crop structures diversified and adapted to local conditions can improve the economic and agronomic performance of small farms when they are integrated with financial management, agricultural advisory services and accessible public policies.

Keywords: *small farms, crop diversification, crop rotations, legumes, cover crops, economic efficiency, agronomic resilience, family farming*

HOW CAN THE ECONOMIC POTENTIAL OF FARMLAND BE EVALUATED? A PROPOSAL FOR A NATIONAL METHODOLOGICAL FRAMEWORK FOR THE CZECH REPUBLIC BASED ON LOCAL SOIL AND CLIMATE CONDITIONS

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Abstract

Economic evaluation and valuation of agricultural land are essential tools for assessing its economic production potential. A wide range of methodological approaches is currently used, differing in their methodological principles, the structure of cost and revenue components included in the calculations, and the level of assessment applied. These differences significantly influence the interpretation and comparability of the resulting economic indicators.

The aim of this study is to compare selected methodological approaches used for evaluating the economic potential of agricultural land and to identify the principal methodological differences in the construction of economic indicators. The analysis focuses on approaches applied in the Czech Republic as well as selected international methodological frameworks, including rental-based approaches, farm-level economic assessment systems, and land valuation methodologies.

The study is based on a comparative analysis of methodological documents and relevant scientific literature. Attention is paid to the treatment of agricultural subsidies, labour costs, capital costs, land rent, depreciation, and to the relationship between economic indicators and soil and climatic conditions.

The results demonstrate that the analysed approaches differ not only in the construction of economic indicators but also in their underlying concepts of economic land evaluation and their practical applications. The Czech methodology is distinguished by a normative approach that models the economic production potential of agricultural land using differentiated cost and revenue parameters reflecting soil and production conditions. In contrast, most international approaches rely primarily on the actual economic performance of agricultural holdings or on long-term economic characteristics used for land valuation.

The comparative analysis made it possible to formulate the fundamental principles of a reference methodological framework for the economic evaluation of agricultural land. The proposed framework preserves the normative principle of economic assessment while ensuring a clear definition of cost and revenue components and maintaining a strong link between economic indicators and soil and production conditions. The proposed methodology provides a basis for further analytical applications in agricultural economics, agricultural policy impact assessment, and agricultural land valuation.

Keywords: *agricultural land; economic evaluation; economic potential; production potential; Gross Annual Rental Effect (HRRE); Evaluated Soil-Ecological Units (BPEJ); land valuation; normative approach*

Acknowledgments: *This paper was prepared within the framework of an internal research project of the Institute of Agricultural Economics and Information (IAEI) focused on methodological approaches to the economic evaluation of agricultural land and the assessment of its production potential in the Czech Republic.*

A COMPARATIVE ASSESSMENT OF PRODUCERS' AND CONSUMERS' PERCEPTIONS, MOTIVATIONS, AND MARKET BARRIERS IN THE ORGANIC WINE SECTOR

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Abstract

The organic wine sector has attracted increasing interest in the context of sustainable agriculture and the European Green Deal; however, its market development remains uneven, particularly in Eastern European countries. This study aims to analyze and compare the perceptions, motivations, and barriers associated with organic wine from the perspective of two key actors in the value chain: producers and consumers.

The research is based on two structured questionnaires administered to organic wine producers and wine consumers. The producer-oriented questionnaire explores motivations for adopting organic viticulture, perceived market barriers, the importance of certification, pricing, labeling, and marketing strategies, as well as future development perspectives for the sector. The consumer questionnaire focuses on consumption behavior, the level of knowledge regarding organic wine, trust in organic certification, willingness to pay a price premium, and the factors influencing purchasing decisions.

Descriptive and comparative statistical analyses reveal a significant gap between producers' and consumers' perceptions, particularly with regard to organic certification, price expectations, and consumers' level of information. While producers emphasize the essential role of certification, consumer education, and environmental benefits in the success of organic wine, consumers display a moderate willingness to pay a premium price and a certain degree of skepticism toward organic labels.

The findings suggest that improving communication strategies, increasing labeling transparency, and implementing targeted educational campaigns may help reduce this gap and support the sustainable development of the organic wine market. The study provides relevant insights for producers, policymakers, and marketing specialists interested in strengthening organic wine consumption in emerging markets.

Keywords: *organic wine; consumer perception; producers' motivations; organic certification; sustainable viticulture; Eastern Europe*

PROFESSIONAL AUTHORITY VERSUS ALGORITHMIC SUPPOSITIONS: EVALUATING THE ADOPTION OF DIGITAL TOOLS FOR PESTICIDE MANAGEMENT IN ROMANIAN ARABLE FARMING

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Abstract

Meeting the sustainability goals of the Green Deal relies heavily on how effectively European agriculture integrates digital tools. However, as the Joint Research Center 2025 report indicates, this implementation remains inconsistent across Member States. While European Union policies promote digitisation as a technical solution for reducing the use of pesticides, farmers' decision-making mechanisms remain insufficiently explored in the context of emerging markets. This study presents preliminary findings from semi-structured interviews with arable farmers in Romania, analysing barriers to adopting pesticide-related Decision Support Systems.

The analysis shows that digital adoption among arable farmers is strongly influenced by the intended commercial destination of the harvest and the associated quality and compliance requirements. While farmers producing for strict retail standards implement rigorous monitoring to reduce the risk of residue rejection, those cultivating volume crops are driven primarily by cost minimisation rather than input optimisation.

A significant psychological barrier emerges from the tension between traditional "agronomic flair" (based on experiential knowledge) and algorithmic recommendations regarding pesticide use. Participants frequently perceive Artificial Intelligence outputs as theoretical suppositions rather than actionable facts, conditioning their trust on mandatory human validation in the field. Paradoxically, the study identifies a pervasive layer of "shadow digitisation". While rejecting expensive formal DSS farmers actively utilise low-tech surrogates, such as generative AI for treatment schemas and social media for peer consultancy, to manage agronomic uncertainty. Consequently, the findings suggest that adoption is stalled not by a lack of technical access, but by a mismatch between the "black box" nature of AI and the farmers' imperative for direct control.

CROP PROTECTION STANDARDS IN SOYBEAN PRODUCTION: THE EUROPEAN UNION AND MERCOSUR UNDER TRADE LIBERALIZATION

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Abstract

The EU–Mercosur Partnership Agreement has renewed interest in regulatory differences affecting crop protection, agricultural competitiveness and sustainable food production. As the European Union remains highly dependent on soybean imports from Mercosur countries, understanding these regulatory asymmetries is essential for agricultural policy and resistance management.

This study compared soybean crop protection systems in the European Union (represented by Poland) and Mercosur countries using official regulatory databases and publicly available information. The analysis focused on the availability of registered herbicides, fungicides, insecticides and biological plant protection products, together with the diversity of pesticide sites of action and their implications for resistance management.

Pronounced regulatory asymmetries were identified across all categories of plant protection products. Compared with the European Union, Mercosur countries have access to six times more herbicide active substances, nineteen times more chemical fungicides, forty-seven times more chemical insecticides and over fifty times more biological fungicide strains. Overall, approximately 100 active substances used in Mercosur soybean production are not approved in the European Union. The broader portfolio of registered products enables more diversified crop protection programmes, greater flexibility in rotating pesticide sites of action and more effective resistance management.

The findings indicate that regulatory asymmetries influence crop protection capacity, production resilience and agricultural competitiveness. Future implementation of international trade agreements should therefore seek an appropriate balance between market liberalization, food safety, environmental protection and the long-term sustainability of crop production systems.

Keywords: *plant protection products, pesticide regulation, integrated crop protection, resistance management, agricultural policy, food safety*

DEREGULATING GENE-EDITED CROPS IN THE EU: 2026 DEVELOPMENTS AND CHALLENGES FOR ENVIRONMENTAL LAW AND BIODIVERSITY PROTECTION

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Abstract

This paper examines the evolving regulatory arc of New Genomic Techniques (NGTs) in the European Union, focusing on the pivotal 2025-2026 developments following the provisional political agreement reached in December 2025 between the European Parliament and Council. The analysis traces the shift from the stringent precautionary framework established under the 2001 GMO Directive and reinforced by the 2018 European Court of Justice ruling, which classified NGTs as GMOs requiring case-by-case risk assessment, to a more innovation-oriented approach. From a European environmental law perspective, the paper critically evaluates this deregulation against the precautionary principle (enshrined in Article 191 TFEU), which mandates preventive action in the face of scientific uncertainty to avoid adverse effects on human health, the environment, and biodiversity. While proponents highlight potential sustainability benefits—such as climate-resilient crops requiring fewer pesticides and fertilizers—critics, including environmental NGOs, argue that exempting NGT-1 plants creates regulatory gaps, bypassing thorough ex-ante risk evaluation and potentially undermining biodiversity protection through unmonitored long-term ecological interactions. The study concludes that the 2026 framework represents a paradigm shift that risks diluting core precautionary safeguards, calling for enhanced post-market monitoring.

Keywords*: biodiversity, genetic modification, gene editing, GMOs, NGTs, EU law.*

POLICY FRAMEWORK ON FRAUD IN THE AGRICULTURAL SECTOR IN THE REPUBLIC OF MOLDOVA

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Abstract

Fraud in the agricultural sector is one of the main challenges affecting the sustainable development of agriculture and food security, with major economic, social and institutional implications. In the context of globalization, the digitization of agricultural processes and the intensification of financial flows to support farmers, the development of an effective anti-fraud policy framework becomes a strategic necessity for modern states. The agricultural sector is vulnerable to multiple forms of fraud, including the illegal use of subsidies, falsification of financial documents, tax evasion, marketing of counterfeit agricultural products, misappropriation of European funds and administrative corruption in the process of providing financial support to farmers. These practices affect the competitiveness of agricultural producers, reduce investor confidence and generate significant losses for the public budget.

Keywords: *agricultural fraud, anti-fraud policies, agricultural sector, agricultural subsidies, financial control, institutional transparency, corruption, economic security, digitalization, sustainable development.*

EVALUATION OF SEMEN QUALITY IN ENGLISH SPRINGER SPANIEL DOGS

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Abstract

Semen evaluation is an important component of canine andrological examination and provides information on reproductive potential and the suitability of semen for assisted reproduction techniques. The aim of the study was to evaluate selected semen quality parameters in English Springer Spaniel dogs.

The study was performed using complete ejaculates collected from eight English Springer Spaniel dogs with FCI pedigree registration. Semen was collected manually in the presence of an estrous bitch. Semen evaluation included ejaculate volume, sperm concentration, total sperm count in the ejaculate, sperm motility assessed using a computer-assisted semen analysis (CASA) system, sperm plasma membrane integrity assessed with SYBR-14/PI staining (PMI), sperm mitochondrial membrane potential assessed using JC-1/PI staining (MMP), and sperm morphology.

The mean ejaculate volume was similar in dogs aged 2–3 years and 4–5 years, whereas the lowest values of this parameter were recorded in dogs below 1 year of age. A similar tendency was observed for the total sperm count in the ejaculate. CASA assessment showed that the percentages of total motile spermatozoa (TMOT) and progressively motile spermatozoa (PMOT) were similar in both groups of dogs aged 2–3 years and 4–5 years, whereas the lowest values of these parameters were recorded in dogs below 1 year of age. With regard to PMI, MMP, and the percentage of morphologically normal spermatozoa, ejaculates collected from dogs belonging to the 2–3-year and 4–5-year age groups met the criteria of normospermia, whereas ejaculates obtained from dogs below 1 year of age were characterized by lower values of the analyzed parameters.

The results indicate that ejaculates collected from the examined English Springer Spaniel dogs aged 2–5 years met the criteria of normospermia.

Keywords: *dog, English Springer Spaniel, semen evaluation, spermatozoa, CASA*

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SPACE FOOD AND FUTURE FOOD

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Abstract

Research on food consumed in space has contributed to the development of food technology on Earth. Funding that was otherwise unavailable for such research was secured through space exploration programs. This presentation outlines the history of space food development, from the earliest flights to the present day, and analyzes development trends, particularly with a view to future missions to Mars. The transit food system will be similar to the ISS food system, but the products must have three- to five-year shelf lives. Food packages and heating food items in a similar fashion to ISS system.

The Mars surface food system will be similar to a vegetarian diet. Once crewmembers arrive on the surface and establish living quarters, they can start growing crops. Possible crops that could be grown and harvested include potatoes (sweet and white), soybeans, wheat, peanuts, dried beans, tomatoes, herbs, carrots, radishes, cabbage and rice. New solutions are being sought to produce foods with a favorable amino acid profile, with a particular focus on products derived from fungi or yeast. A plant-based food system is the most likely scenario because of water scarcity on Mars, higher energy costs for animal production, radiation risks: animals are more vulnerable to high radiation on Mars than plants. Animals produce methane and consume oxygen, which could disrupt the fragile air balance in small, sealed habitat domes. Conversely, plants turn carbon dioxide into oxygen. The plant-based approach allows for higher production in a smaller, controlled area through hydroponics or aeroponics.

Astronauts can lose approximately 15% overall muscle mass throughout a long mission and up to 30% of their lower-body muscle mass. The Advanced Resistive Exercise Device designed by NASA to allow for resistance training in zero gravity. System of vacuum tubes simulate the process of free weight exercises, such as squats, deadlifts, and calf raises and in this way it prevents muscle atrophy.

Keywords: *space food, microgravity, Mars, muscle atrophy*

LIVESTOCK BREEDING IN MEDIEVAL SHKODRA (SKADAR) ACCORDING TO THE STATUTE FROM THE FIRST HALF OF THE 14TH CENTURY

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Abstract

The earliest written legal provisions concerning animal husbandry among the Serbs originated in Byzantium at the beginning of the 11th century. In Raška (Rascia), the first legal regulations relating to livestock breeding emerged at the end of the twelfth and the beginning of the thirteenth century on the estates of Studenica and Mileševa monasteries. Certain provisions may also be found in the Old Serbian Law and in the Žiča Chrysobull, both dating from the same period. This process continued throughout the thirteenth and fourteenth centuries. Among the most significant charters issued in the early fourteenth century containing provisions on animal husbandry are the Banjska Charter (St Stephen Chrysobull) and the Dečani Chrysobull. Such regulations are mainly found in sections entitled The Law for Church Dependants, *The Law on the Vlachs, and The Military Law. After provisions concerning agriculture, regulations related to livestock breeding are the most numerous. Rules governing animal husbandry can also be found in urban statutes. The Statute of Scutari (today Shkodër) was enacted before 16 April 1346, the date on which Stefan Dušan was crowned Emperor. Of its 279 articles, approximately 40 deal with livestock and related matters. These provisions may be divided into general regulations concerning livestock, as well as articles referring to large and small livestock and to specific animals, including bulls (oxen), cattle, horses, donkeys, sheep, and pigs. The statute also contains regulations concerning animal products such as meat, cheese, and hides. Furthermore, it includes provisions regarding slaughterhouses, butchers, customs duties on meat, obligations of livestock breeders, weights and measures, price regulation, taxes and fees, and various prohibitions, such as the keeping of livestock within the city. Particularly interesting is a provision concerning an insult punishable by law: calling a person a donkey. No other animal is mentioned in this context. The considerable number of provisions relating to livestock demonstrates the importance of animal husbandry not only for nutrition but also for the overall economy of the city of Scutari. These regulations also provide valuable insights into the types of livestock that were most commonly raised and the relative significance of different forms of animal husbandry.*

Keywords: *Raška, legislation, animal husbandry, Scutari, Statute of Scutari, Zeta*

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