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SUSTAINABLE POSTHARVEST AND
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INOPTEP 2025
and
XXXVII NATIONAL CONFERENCE
PROCESSING AND ENERGY
IN AGRICULTURE
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INOPTEP 2025
i
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CONTENT

QUALITY OF SMOKED CHICKEN BREASTS PRODUCED UNDER TRADITIONAL CONDITIONS WITH THE ADDITION OF VARIOUS SPICES

Munevera BEGIĆ[1], Semina PINJIĆ[1], Eldar HASANDIĆ[1], Lejla BIBER[1]
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The aim of the research was to examine the quality of smoked chicken breasts produced under traditional conditions with the addition of various spices. Experimental production of smoked chicken breasts was carried out at a traditional meat processor in the Visoko municipality. For the purpose of the research, five groups of smoked chicken breasts were produced to which an equal amount of salt was added. After everything was salted, four samples were each seasoned with one of the following - rosemary, chili, garlic or turmeric, and the fifth group was the control one. Smoking of chicken breasts was carried out in a traditional smokehouse with an open fire, and exclusively dry and healthy beech wood (*Fagus sylvatica*) logs were used for smoke production. Sensory and technological-chemical tests were performed on the tested samples. According to the sensory evaluation, all tested samples of smoked chicken breasts had an acceptable to very acceptable overall impression. The highest average overall impression score was given to the samples of smoked chicken breast with rosemary (4.60) and the lowest to the samples with garlic (3.10). The samples of smoked chicken breasts with rosemary had the highest scores for smell, taste and overall impression, while the samples of the control group (without added spices) had the highest scores for cross-sectional appearance, texture and aroma. The two groups of samples mentioned had the best color scores (4.60) compared to the other tested groups. The samples with turmeric had the best external appearance. The results of technological and chemical tests showed that the samples with chili had the highest fat content compared to the other tested groups. The samples with garlic had the highest NaCl and ash content, the samples with rosemary had the highest moisture content, and the samples with turmeric and rosemary had the highest protein content. The samples of the control group had the highest pH value, and the samples with the addition of turmeric had the highest water activity value. The results of the conducted research show the possibility of producing smoked chicken breasts under traditional conditions. Also, the quality test results show good quality of smoked chicken breasts with the addition of different spices and the possibility of increasing the assortment of this type of product on the market.

Key words: *smoked chicken breasts, traditional production, spices, sensory quality, technological-chemical parameters*

KVALITET DIMLJENIH PILEĆIH PRSA PROIZVEDENIH U TRADICIONALNIM USLOVIMA SA DODATKOM RAZLIČITIH ZAČINA

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Cilj istraživanja bio je ispitati kvalitet dimljenih pilećih prsa proizvedenih u tradicionalnim uslovima sa dodatkom različitih začina. Eksperimentalna proizvodnja dimljenih pilećih prsa provedena je kod tradicionalnog mesoprerađivača na području općine Visoko. Za potrebe istraživanja proizvedeno je pet grupa dimljenih pilećih prsa u koje je dodana jednaka količina soli. Nakon soljenja, u četiri grupe uzoraka su dodani ruzmarin, čili, bijeli luk i kurkuma u jednakim količinama a peta grupa je bila kontrolna. Dimljenje pilećih prsa provedeno je u tradicionalnoj pušnici sa otvorenim ložištem a za proizvodnju dima koristile su se isključivo suhe i zdrave cjepanice bukovog drveta (*Fagus sylvatica*). Na ispitivanim uzorcima urađena su senzorna i tehnološko-hemijska ispitivanja. Provedenom senzornom ocjenom svi ispitivani uzorci dimljenih pilećih prsa imali su prihvatljiv do veoma prihvatljiv ukupni dojam. Najveću prosječnu ocjenu ukupnog dojma imali su uzorci dimljenih pilećih prsa sa dodatkom ruzmarina (4,60) a najmanju uzorci sa dodatkom bijelog luka (3,10). Uzorci dimljenih pilećih prsa sa dodatkom ruzmarina imali su najveće vrijednosti ocjena za miris, okus i ukupan dojam, dok uzorci kontrolne grupe (bez dodatka začina) najveće vrijednosti ocjene izgleda presjeka, teksture i arome. Pomenute dvije grupe uzoraka imale su najbolje ocjene boje (4,60) u odnosu na druge ispitivane grupe. Najbolje ocijenjen vanjski izgled imali su uzorci sa dodatkom kurkume. Rezultati tehnološko-hemijskih ispitivanja pokazali su da statistički značajno najveći sadržaj masti imali su uzorci sa dodatkom čilija u odnosu na druge ispitivane grupe. Uzorke sa dodatkom bijelog luka karakterisao je statistički signifikatno najveći sadržaj NaCl-a i pepela, uzorke sa dodatkom ruzmarina najveći sadržaj vode, a uzorke sa dodatkom kurkume i ruzmarina najveći sadržaj proteina. Uzorci kontrolne grupe imali su najveću vrijednost pH a uzorci sa dodatkom kurkume aktiviteta vode. Rezultati provedenog istraživanja pokazuju mogućnost proizvodnje dimljenih pilećih prsa u tradicionalnim uslovima. Također, rezultati ispitivanja kvaliteta pokazuju dobar kvalitet dimljenih pilećih prsa sa dodatkom različitih začina i mogućnost povećanja asortimana ove vrste proizvoda na tržištu.
Ključne riječi: *dimljena pileća prsa, tradicionalna proizvodnja, začini, senzorni kvalitet, tehnološko-hemijski parametri.*

APPLICATION OF INFORMATION TECHNOLOGIES IN BEEKEEPING FOR PRODUCTION IMPROVEMENT AND BIODIVERSITY CONSERVATION

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Honey bees, such as the western honey bee (*Apis mellifera*), are of great social, ecological, and economic importance. However, the beekeeping sector faces numerous challenges. For over three decades, beekeepers have experienced significant colony losses during winter due to various health threats, including parasites, pathogens, pesticide exposure, and a lack of forage resources. Additionally, the adverse effects of climate change in certain regions further exacerbate these issues. Meanwhile, digitalization is rapidly transforming the agri-food sector's pursuit of sustainability and resilience. Like many modern production systems, beekeeping is also advancing towards digitalization. As part of the "BeeAlive – Climate Change Mitigation and Beekeeping Development" project, the potential application of information technologies in beekeeping was explored through the development of Initial Action Plans (IAPs) for beekeeping development in two municipalities, Milići and Tešanj (Bosnia and Herzegovina). This research aimed to identify key challenges in the beekeeping sector, assess the impact of climate change on honey production, and explore technological solutions for optimizing beekeeping practices. Geographical and climatic factors, biodiversity, agricultural land structure, and the potential for planting nectariferous plants were analyzed. The results indicate untapped resources, the need for better management of bee pastures, and challenges posed by climate change, which directly affect honey yield reduction and increase the duration of forage scarcity periods. The implementation of information technologies was highlighted as a key solution, including digital registries of beekeepers and apiaries, IoT sensors for monitoring hive micro conditions, and geolocation systems for tracking nectariferous plants and optimizing bee migration. Special emphasis was placed on introducing digital platforms that enable real-time data analysis, improve productivity, and reduce losses in beekeeping.
The implementation of the proposed technological solutions would allow for more efficient planning of beekeeping production, better adaptation to climatic changes, and increased sustainability of the sector. The research results underscore the need for a multidisciplinary approach in beekeeping, where synergy between science, technology, and local communities would facilitate the long-term development of the beekeeping industry. Digitalization of beekeeping would not only enhance honey production but also contribute to biodiversity conservation and ecosystem protection, which is crucial in the context of global climate change.
***Key words**: beekeeping, digitalization, biodiversity.*

Acknowledgment of funding: BeeAlive 2 – Climate Change Mitigation and Beekeeping Development, NODAS (Association for Development and Promotion of Society in BiH), Contract No: PBOSBIH258-24-26-SER1-SM

PRIMJENA INFORMACIONIH TEHNOLOGIJA U PČELARSTVU ZA UNAPREĐENJE PROIZVODNJE I OČUVANJE BIODIVERZITETA

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Pčele medarice kao što je medonosna pčela (*Apis mellifera*) su od velike društvene, ekološke i ekonomske važnosti. Ipak, izazovi s kojima se suočava pčelarski sektor su višestruki. Više od tri desetljeća pčelari su iskusili velike gubitke kolonija pčela tokom zime zbog niza prijetnji povezanih sa zdravljem kao što su paraziti, patogeni, izloženost pesticidima ali i nedostatak pčelinje paše. Osim ovih navedenih tu su i nepovoljni utjecaji klimatskih promjena u određenim regijama. U međuvremenu, digitalizacija brzo transformiše poljoprivredno-prehrambeni sektor u njegovoj potrazi da postane održiviji i otporniji. Kao i mnoge privredne grane i savremeni proizvodni sistemi tako i pčelarstvo ide prema digitalizaciji. U okviru projekta „BeeAlive – Ublažavanje klimatskih promjena i razvoj pčelarstva“, predstavila se mogućnosti primjene informacionih tehnologija u pčelarstvu kroz izradu Inicijalnih Akcionih Planova (IAP) za razvoj pčelarstva u dvije opštine Milići i Tešanj (Bosna i Hercegovina). Cilj ovog istraživanja bio je identifikacija ključnih izazova u sektoru pčelarstva, procjena klimatskih uticaja na proizvodnju meda i pronalazak tehnoloških rješenja za optimizaciju pčelarske proizvodnje. Analizirani su geografski i klimatski faktori, biodiverzitet, struktura poljoprivrednog zemljišta i potencijal za sadnju medonosnog bilja. Rezultati ukazuju na neiskorištene resurse, potrebu za boljim upravljanjem pčelinjim pašama i izazove uzrokovane klimatskim promjenama, koji direktno utiču na smanjenje prinosa meda i povećanje bezpašnih perioda. Kao ključno rješenje istaknuta je implementacija informacionih tehnologija, uključujući digitalne registre pčelara i pčelinjaka, IoT senzore za praćenje mikrouslova u košnicama, te geolokacijske sisteme za evidenciju medonosnog bilja i optimizaciju selidbe pčela. Poseban naglasak stavljen je na uvođenje digitalnih platformi koje omogućavaju analizu podataka u realnom vremenu, poboljšanje produktivnosti i smanjenje gubitaka u pčelarstvu. Implementacija predloženih tehnoloških rješenja omogućila bi efikasnije planiranje pčelarske proizvodnje, bolje reagovanje na promjene u klimatskim uslovima i povećanje održivosti sektora. Rezultati istraživanja ukazuju na potrebu za multidisciplinarnim pristupom u pčelarstvu, u kojem bi se sinergijom nauke, tehnologije i lokalnih zajednica omogućio dugoročan razvoj pčelarske industrije. Digitalizacija pčelarstva ne samo da bi unaprijedila proizvodnju meda, već bi i doprinijela zaštiti biodiverziteta i ekosistema, što je od ključne važnosti u kontekstu globalnih klimatskih promjena.
***Key words**: pčelarstvo, digitalizacija, biodiverzitet.*

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EFFECTS OF CHOKEBERRY AND TART CHERRY BASED DIETARY SUPPLEMENTS IN DYSLIPIDEMIC INDIVIDUALS

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The prevalence of obesity has increased dramatically over the last several decades. It is estimated the United States approximately 40% of women and 35% of men are obese (BMI >30 kg/m2). It is of great concern is that the prevalence of obesity has also markedly increased in children. Obesity is associated with alterations in lipid metabolism, insulin resistance and metabolic syndrome, particularly when the excess adipose tissue is located in an intra-abdominal location or in the upper chest. Moreover, obesity is a great risk factor for the development of cardiovascular disease. Epidemiological studies indicated that high intake of dietary polyphenols is connected with lower risk for development of chronic diseases such as cardiovascular, diabetes, obesity, neurodegenerative. That is why polyphenols are nowadays common ingredients in lot of dietary supplements and functional foods. Polyphenols are plant secondary metabolites widely distributed in medicinal plants, red wine, many fruits and vegetables, and their derived products. According to some researches, there is 200−300 mg of dietary polyphenols in every 100 g of fresh fruits or vegetables, and the total dietary intake of polyphenols in adults is from 700 to 1700 mg/day. Various bioactivities are connected with polyphenols such as antioxidant, antimicrobial, anti-inflammatory, antineurodegenerative, anticancer, antidiabetic, antiaging etc. Previous studies showed that consumption of *Aronia melanocarpa* extract is correlated with a positive effect on body weight, total cholesterol, low and high-density lipoproteins. The aim of our study was to evaluate the effect of combined oral consumption of two dietary supplements based on chokeberry and tart cherry juices over a period of 90 days on cholesterol, LDL, HDL, triglycerides, thickness of subcutaneous fatty tissue in different areas and safety in 46 participants with dyslipidemia. At the level of individual respondents 11 respondents (24%) had a significant improvement in cholesterol, HDL and LDL, 10 respondents (22%) had an improvement in cholesterol and LDL while there was an improvement in triglycerides in 19 subjects (41%). Although a slight decrease in cholesterol, HDL, LDL, and triglyceride levels was observed at the group level, it was not statistically significant. On the other hand, statistically significant improvement (decrease) was recorded in the thickness of subcutaneous fatty tissue in different areas i.e. in the middle of the front abdominal wall (right and left) and in the middle of the front side of the thigh (right and left). Moreover, statistically significant improvement in BMI (body mass index) was recorded from 36.53±10.72 to 30.33±6.70 (p-value 0.0001). The levels of creatinine, urea, ALT and AST values which remained within normal limits, indicated that dietary supplements did not have negative effects on the liver and kidneys during the study.
***Key words**: chokeberry, tart cherry, juices, dyslipidemia, obesity.*

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Prevalenca gojaznosti dramatično se povećala tokom poslednjih nekoliko decenija. Procenjuje se da je u Sjedinjenim Američkim Državama oko 40% žena i 35% muškaraca gojazno (BMI >30 kg/m^2). Veoma je zabrinjavajuće da je prevalenca gojaznosti takođe značajno porasla kod dece. Gojaznost je povezana sa promenama u metabolizmu lipida, insulinskom rezistencijom i metaboličkim sindromom, posebno kada se višak masnog tkiva nalazi na intraabdominalnoj lokaciji ili u gornjem delu grudnog koša. Štaviše, gojaznost je veliki faktor rizika za razvoj kardiovaskularnih bolesti. Epidemiološke studije su pokazale da je visok unos polifenola u ishrani povezan sa manjim rizikom od razvoja hroničnih bolesti kao što su kardiovaskularne, dijabetes, gojaznost, neurodegenerativne. Zato su polifenoli danas uobičajeni sastojci mnogih dodataka ishrani i funkcionalne hrane. Polifenoli su biljni sekundarni metaboliti široko rasprostranjeni u lekovitom bilju, crnom vinu, mnogim vrstama voća i povrća i proizvodima od njih. Prema nekim istraživanjima, u unosom 100 g svežeg voća ili povrća obezbedi se oko 200-300 mg polifenola u ishrani, a ukupan unos polifenola hranom kod odraslih se kreće od 700 do 1700 mg/dan. Različite biološke aktivnosti su povezane sa polifenolima kao što su antioksidativna, antimikrobna, antiinflamatorna, antineurodegenerativna, antikancerogena, antidijabetična, antiaging idr. Ranija istraživanja su pokazala da je konzumacija ekstrakta vrste *Aronia melanocarpa* u korelaciji sa pozitivnim dejstvom na telesnu težinu, ukupni holesterol, lipoproteine male i velike gustine. Cilj našeg istraživanja bio je da se proceni efekat kombinovane oralne konzumacije dva dijetetska suplementa na bazi sokova od aronije i višnje u periodu od 90 dana na holesterol, LDL, HDL, trigliceride, debljinu potkožnog masnog tkiva u različitim regijama i bezbednost suplemenata kod 46 učesnika sa dislipidemijom. Na nivou pojedinačnih ispitanika 11 ispitanika (24%) imalo je značajno poboljšanje u nivou holesterola, HDL i LDL, 10 ispitanika (22%) imalo je poboljšanje u nivou holesterola i LDL dok je došlo do poboljšanja nivoa triglicerida kod 19 ispitanika (41%). Iako je uočeno blago smanjenje nivoa holesterola, HDL, LDL i triglicerida na nivou cele grupe, to nije bilo statistički značajno. Sa druge strane, zabeleženo je statistički značajno poboljšanje (smanjenje) debljine potkožnog masnog tkiva u različitim regijama, odnosno na sredini prednjeg trbušnog zida (desno i levo) i na sredini prednje strane butine (desna i leva). Takođe, zabeleženo je statistički značajno poboljšanje BMI (indeks telesne mase) sa prosečno 36,53±10,72 na 30,33±6,70 (p-vrednost 0,0001). Nivoi kreatinina, uree, ALT i AST koji su ostali u granicama normale, ukazuju na to da dijetetski suplementi nisu imali negativne efekte na jetru i bubrege tokom studije.
***Ključne reči**: aronija, višnja, sokovi, dislipidemija, gojaznost*

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BIOACTIVE POTENTIAL OF *Arbutus unedo* L. LEAVES: INFLUENCE OF GEOGRAPHICAL LOCATION, EXTRACTION METHOD AND SOLVENT TYPE

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Arbutus unedo L. (strawberry tree) leaves are recognized for their rich composition of bioactive compounds, including phenolic compounds, which possess significant antioxidant properties. This study investigates the bioactive potential of *A. unedo* leaves by examining the effects of geographical location, extraction methods, and solvent type on the recovery and composition of bioactive compounds. Leaf samples of *A. unedo* were collected from two locations in the Republic of Croatia: the island of Mali Lošinj (northern location) and the island of Vis (southern location). Conventional techniques, such as reflux heating and Soxhlet extraction, were compared with non-conventional ultrasound-assisted method to evaluate their efficiency in isolating antioxidant bioactives. Three eco-friendly solvents, distilled water, 70% ethanol, and ethyl acetate, were chosen for their low environmental impact and effectiveness in isolating bioactive compounds, ensuring sustainability while maximizing the recovery of bioactive constituents. All extracts were evaluated for total phenolic content (TPC), hydroxycinnamic acids (HCA), flavonols (FL) and condensed tannins (CT), as well as *in vitro* antioxidant capacity using FRAP and ABTS assays via spectrophotometric methods. Geographical variations significantly influenced the bioactive profiles of the leaves, with significant differences in the abundance and diversity of bioactive antioxidants (TPC and CT). The extraction method did not appear to significantly affect the stability of the bioactive compounds. However, solvent type proved emerged as a critical factor, impacting both the yield and stability of the extracted compounds, with 70% ethanol identified as the optimal extraction solvent. These findings highlight the importance of tailoring the extraction solvent to the unique characteristics of *A. unedo* L. leaves. Moreover, the study underscores the industrial relevance of *A. unedo* L. leaves as a sustainable and renewable source of natural antioxidants, with potential applications in the food and pharmaceutical industries. The ability to optimize bioactive recovery through careful selection of geographical growing locations, solvents types, and extraction methods demonstrates the value of this species in promoting innovative and eco-friendly solutions for various purposes. Overall, the study provides a comprehensive understanding of the factors influencing the bioactive potential of *A. unedo* L. leaves and offers practical insights into maximizing their antioxidant properties. These findings pave the way for future research and commercial utilization of this underutilized plant species.

***Key words**: Arbutus unedo L., bioactive compounds, growing location, extraction methods, sustainable solvents.*

BIOAKTIVNI POTENCIJAL LISTOVA *Arbutus unedo* L.: UTJECAJ GEOGRAFSKE LOKACIJE, METODE EKSTRAKCIJE I VRSTE OTAPALA

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Listovi *Arbutus unedo* L. (obična planika) prepoznati su po bogatom sastavu bioaktivnih spojeva, uključujući fenolne spojeve s izraženim antioksidativnim svojstvima. Ovo istraživanje ispituje bioaktivni potencijal listova *A. unedo* analizirajući utjecaj geografske lokacije uzgoja, metode ekstrakcije i vrste otapala na izolaciju i sastav bioaktivnih spojeva. Uzorci listova *A. unedo* prikupljeni su na dvije lokacije u Republici Hrvatskoj: na otoku Malom Lošinju (sjeverna lokacija) i otoku Visu (južna lokacija). Konvencionalne tehnike ekstrakcije, poput grijanja uz povrat i ekstrakcije po Soxhlet-u, uspoređene su s inovativnom metodom ekstrakcije uz pomoć ultrazvuka kako bi se procijenila njihova učinkovitost u izolaciji antioksidativnih bioaktivnih spojeva. Korištena su tri ekološki prihvatljiva otapala – destilirana voda, 70% etanol i etil-acetat – odabrana zbog niskog utjecaja na okoliš i učinkovitosti u izolaciji bioaktivnih spojeva, čime se osigurava održivost uz maksimalno izdvajanje bioaktivnih komponenti. U svim ekstraktima spektrofotometrijski je određen je sadržaj ukupnih fenola (TPC), hidroksicimetnih kiselina (HCA), flavonola (FL) i kondenziranih tanina (CT), kao i *in vitro* antioksidativni kapacitet pomoću FRAP i ABTS testova. Geografska lokacija uzgoja značajno je utjecala na bioaktivni sastav listova, pri čemu su zabilježene značajne razlike u sastavu i udjelima određenih bioaktivnih spojeva (TPC i CT). Metoda ekstrakcije nije imala značajan utjecaj na stabilnost ispitanih bioaktivnih spojeva. Međutim, vrsta otapala pokazala se ključnim čimbenikom koji utječe na prinos i stabilnost izdvojenih spojeva, pri čemu je 70% etanol identificiran kao optimalno otapalo. Rezultati dobiveni ovim istraživanjem naglašavaju važnost prilagodbe odabira otapala specifičnim karakteristikama listova *A. unedo* L. Nadalje, istraživanje ističe industrijsku relevantnost listova *A. unedo* L. kao održivog i obnovljivog izvora prirodnih antioksidansa s potencijalnim primjenama u prehrambenoj i farmaceutskoj industriji. Optimizaciju izdvajanja bioaktivnih spojeva iz *A. unedo* listova moguće je ostvariti pažljivim odabirom lokacije uzgoja, vrste otapala i metode ekstrakcije čime se potvrđuje vrijednost ove vrste u promicanju inovativnih i ekološki prihvatljivih rješenja za različite svrhe.
U zaključku, ovo istraživanje pruža sveobuhvatan uvid u čimbenike koji utječu na bioaktivni potencijal listova *A. unedo* L. te nudi praktične smjernice za maksimiziranje njihovih antioksidativnih svojstava. Ovim spoznajama otvara se put budućih istraživanja uz jačanje komercijalnog iskorištavanja ove nedovoljno iskorištene biljne vrste.

***Ključne reči**: Arbutus unedo L., bioaktivni spojevi, lokacija uzgoja, metode ekstrakcije, održiva otapala*

SEED TREATMENT: EVOLUTION AND ALTERNATIVES

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Seed treatments aim to protect seeds and young plants from diseases and pests, and to promote early growth of the plant. The first seed treatments date back to the 19th century, and in the 20th century, specialized devices for seed treatment were developed with capacities that allowed for their industrial application. The most widespread treatments, due to their ease of application and good efficiency, are chemical treatments. Previously, continuous-type seed treatment devices were used, but they have now been almost completely replaced by batch treaters, which feature very precise chemical dosage. Additionally, powdered seed treatment formulations have been replaced by specialized liquid formulations. Apart from the chemical agent, a high-quality adhesive is an essential component of modern treatments. The adhesive ensures the proper application and retention of the chemical agent on the seed until sowing, and it gives the seed a color as a warning that it has been treated. To protect the ecosystem from contamination during sowing, treated seeds undergo the "Heubach" test using a device that simulates the operation of a seeder, after which the amount of dust released, containing the chemical agent, is measured. This test is especially important when insecticidal treatments are used, as spring sowing can overlap with the flowering of certain entomophilous plant species. Additionally, to ensure adequate protection, tests such as the "Loading test" are used to check the amount of active substances on the seed. Alternatives to chemical seed treatments are biological and physical treatments. These are suitable for organic production, where the use of synthetic chemicals is prohibited. Biological treatments are most commonly applied in formulations that can be applied to seeds using standard seed treatment devices. The challenge with these treatments, as they mostly contain live organisms (most often bacteria or fungi), is maintaining their vitality until seed sowing. For this reason, it is recommended to use them immediately before sowing. Physical seed treatments involve the use of physical methods and techniques to improve seed quality. Various physical methods are available to break seed dormancy, and there are also physical seed treatments at industrial capacities that can serve as an alternative to chemical treatments. One such treatment is electron beam treatment, which practically sterilizes the seed. A similar effect on the seed can be achieved through treatment with heated steam. Physical treatments can effectively control seed-borne diseases. The disadvantage of these treatments compared to chemical ones is that they cannot provide long-lasting protection for the seed and young plant, as is the case with some chemical seed treatments. Therefore, in the case of biological seed treatments, a possible approach is the combination of physical treatments for seed sterilization and biological ones that would provide longer-lasting seed protection.

Key words*: seed treatment, chemical treatment, biological treatment, physical treatment*

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TRETMAN SEMENA: EVOLUCIJA I ALTERNATIVE

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Tretmani semena imaju za cilj zaštitu semena i mlade biljke od bolesti i štetočina, kao i podsticanje početnog porasta biljke. Prvi tretmani semena datiraju još iz 19. veka a u 20. veku razvijaju se specijalizovani uređaji za tretman semena sa kapacitetima koji omogućavanju njihovu industrijsku primenu. Najrasprostranjeniji, zbog svoje lake primene i dobre efikasnosti su hemijski tretmani. Nekada su korišćeni uređaji za tretman semena kontinuiranog tipa a sada su ih skoro potpuno potisnuli šaržni zaprašivači koji se odlikuju veoma preciznim doziranjem hemijskog sredstva. Takođe, preparate za tretiranje semena u obliku praška su zamenile specijalizovane tečne formulacije. Pored hemijskog sredstva, neizostavan deo savremenog tretmana je kvalitetan lepak koji omogućava dobro nanošenje i zadržavanje hemijskog sredstva na semenu do setve i daje semenu boju kao način upozorenja da je tretirano. U cilju zaštite ekosistema od kontaminacije prilikom setve, tretirano seme se podvrgava "Heubach" testu pomoću uređaja koji imitira rad sejalice, nakon čega se meri količina oslobođene prašine koja u sebi sadrži hemijsko sredstvo. Ovaj test je posebno značajan kod tretmana insekticidima jer se prolećna setva može poklopiti sa cvetanjem nekih entomofilnih biljih vrsta. Takođe, kako bi se osigurala kvalitetna zaštita, postoje testovi za proveru količine aktivnih materija na semenu kao što je "*Loading test*". Alternative hemijskim tretmanima semena su biološki i fizički tretmani. Oni su pogodni i za organsku proizvodnju gde je upotreba sintetisanih hemijskih sredstava zabranjena. Biološki tretmani su najčešće u takvim formulacijama koje se mogu naneti na seme pomoću standardnih uređaja za tretiranje semena. Izazov kod njih, pošto se uglavnom radi o preparatima koji sadrže žive organizme (najčešće bakterije ili gljive), je očuvanje njihove vitalnosti do setve semena. Zbog ovoga, preporučuje se njihova upotreba nepotrebno pred setvu. Fizički tretmani semena podrazumevaju upotrebu fizičkih metoda i tehnika za poboljšanje kvaliteta semena. Postoje različite fizičke metode za razbijanje dormancije semena a postoje i fizički tretmani semena industrijskih kapaciteta koji mogu biti pandam hemijskim tretmanima. Jedan od ovih tretman je tretman ubrzanim elektronima pomoć u kojih se seme praktično sterilizuje. Takođe, sličan efekat na seme ima tretman zagrejanom vodenom parom. Fizičkim tretmanima se mogu efikasno suzbiti bolesti koje se prenose semenom. Nedostatak ovih tretmana u poređenju sa hemijskim je to što ne mogu da pruže dugotrajniju zaštitu semena i mlade biljke kao što je to slučaj kod nekih hemijskih tretmana semena. Zbog ovoga, u slučaju bioloških tretmana semena moguć pristup je kombinacija fizičkih tretmana za sterilicaziju semena i bioloških koji bi omogućili dugotrajniju zaštitu semena.

***Ključne reči**: tretman semena, hemijski tretman, biološki tretman, fizički tretman*

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COLD PLASMA TO TREAT READY-TO-EAT APPLES: AN ACTIVE SOLUTION AGAINST *ARCOBACTER* SPP. AND *CRONOBACTER* SPP. CONTAMINATION

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Cold plasma technology has emerged as a promising non-thermal approach for food decontamination, offering effective microbial inactivation through a combination of oxidative stress, UV radiation, and charged particles while preserving the intrinsic quality of the treated product. Its application is particularly promising for decontaminating ready-to-eat apple slices. Such products have been implicated in outbreaks involving emerging foodborne pathogens such as *Arcobacter* spp., associated with gastrointestinal illnesses, and *Cronobacter* spp., a critical concern in neonatal infections. In this study, a gaseous cold plasma prototype, operating under the NOx regime, was employed to superficially treat apple slices deliberately inoculated with two strains of *Arcobacter butzleri* and one strain of *Cronobacter* spp. (initial level approximately 4.5 Log CFU/g). The apples were exposed to plasma for 5, 10, 20 and 30 min and were evaluated immediately after the treatment for the viability of the inoculated microorganisms and the changes in the quality parameters, i.e. color, pH. Results revealed that even a 5-minute exposure induced a significant ($p<0.05$) logarithmic reduction for *Arcobacter* spp., though the two strains exhibited different sensitivity. The most susceptible strain resulted below the detection limit after 10 minutes, while the less sensitive one required 20 minutes to achieve undetectable levels. Conversely, *Cronobacter* spp. demonstrated a reduction exceeding 3 logarithmic cycles, albeit showing greater resistance compared to the *Arcobacter* strains. Quality assessments indicated an immediate, albeit slight, decrease in the pH of the apple slices post-treatment, with more pronounced changes observed at longer exposure times. Additionally, extended plasma treatment resulted in notable color modifications, likely due to enzymatic browning. Interestingly, during storage at 4°C, apples treated for shorter times exhibited more significant alterations in appearance over time, suggesting a complex interplay between treatment intensity and post-process quality dynamics.These findings underscore the potential of cold plasma technology as an effective, chemical-free strategy for the superficial decontamination of ready-to-eat apple slices. By enhancing microbial safety and potentially extending shelf-life without resorting to chemical preservatives, this technology aligns with the growing demand for clean-label and minimally processed food products.

Key words*: cold plasma technology, ready-to-eat apples, Arcobacter spp., Cronobacter spp., emerging pathogens, quality parameters.*

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ADVANCEMENTS AND CHALLENGES OF 3D PRINTING IN MODERN AGRICULTURE

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The integration of 3D printing in agriculture represents a significant step forward in how tools, equipment, and technologies are developed and applied to meet the needs of modern farming. By enabling the rapid and cost-effective production of customized components, 3D printing offers practical solutions for challenges such as equipment repairs, resource efficiency, and sustainability. Recent advancements have focused on the use of biodegradable materials, like PLA, as well as durable polymers to manufacture items such as irrigation parts, machine components, and specialized tools for fieldwork.

In addition to traditional applications, 3D printing is being explored for precision agriculture, with the development of soil testing devices, custom drones, and sensor housings that support more efficient and environmentally conscious farming practices. The technology also plays a role in research, such as fabricating experimental setups for plant growth studies and pest management strategies. Another emerging area is the integration of 3D printing with automated agricultural systems, including robotic harvesters and crop-monitoring equipment.

Despite these promising developments, there are still challenges. These include finding materials that can withstand harsh environmental conditions, ensuring compliance with agricultural and safety standards, and scaling up production to meet industry demands. Looking ahead, the combination of 3D printing with digital technologies like artificial intelligence and the Internet of Things presents an opportunity to advance smart farming.

***Key words**: additive manufacturing, 3D printing, agriculture, precision agriculture, challenges.*

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NAPREDAK I IZAZOVI 3D ŠTAMPE U SAVREMENOJ POLJOPRIVREDI

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Integracija 3D štampe u poljoprivredu predstavlja značajan korak napred u načinu na koji se alati, oprema i tehnologije razvijaju i primenjuju kako bi zadovoljili potrebe moderne poljoprivrede. Omogućavajući brzu i isplativu proizvodnju prilagođenih komponenti, 3D štampa nudi praktična rešenja za izazove poput popravki opreme, efikasne upotrebe resursa i održivosti. Skorašnji razvoj i napredak usmeren je na upotrebu biorazgradivih materijala, poput PLA, kao i izdržljivih polimera za proizvodnju predmeta kao što su delovi za sisteme za navodnjavanje, komponente mašina i specijalizovanih alata za rad na terenu.

Pored tradicionalnih primena,istraživanja 3D štampe se sprovode i u oblasti precizne poljoprivrede, razvojem uređaja za analizu zemljišta, prilagođenih dronova i kućišta za senzore koji podržavaju efikasnije i ekološki prihvatljivije aktivnosti u poljoprivredi. Tehnologija takođe igra ulogu u istraživanjima, poput izrade eksperimentalnih postavki za proučavanje rasta biljaka i strategija za kontrolu štetočina. Druga oblast u razvoju je integracija 3D štampe sa automatizovanim poljoprivrednim sistemima, uključujući robotske berače i opremu za praćenje useva.

Uprkos ovim obećavajućim razvojnim pravcima, i dalje postoje izazovi. Oni uključuju pronalaženje materijala koji mogu izdržati teške uslove okoline, osiguranje usklađenosti sa poljoprivrednim i bezbednosnim standardima, kao i povećanje proizvodnje kako bi se zadovoljile potrebe industrije. Gledajući u budućnost, kombinacija 3D štampe sa digitalnim tehnologijama poput veštačke inteligencije i Interneta stvari predstavlja priliku za unapređenje „pametne“ poljoprivrede.

***Ključne reči**: aditivna proizvodnja, 3D štampa, poljoprivreda, precizna poljoprivreda, izazovi.*

IMPACT OF DIFFERENT MASHING REGIMES ON TECHNOLOGICAL PARAMETERS OF ALCOHOL-FREE BEER

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Beer is the world's third most consumed beverage, following water and tea, and is the most popular alcoholic drink globally. It has been scientifically proven that moderate beer consumption is associated with a range of positive health effects on the human body, which originate from the barley (malt) and hops compounds, two essential ingredients in beer production. However, these health benefits of beer are limited by negative effects associated with its alcohol content. As interest in health grows, along with warnings about alcohol abuse, consumer preference for low-alcohol and alcohol-free beer is increasing. The global demand for low-alcohol and non-alcoholic beverages has risen due to changing consumer preferences towards healthier lifestyles, stricter alcohol-related regulations, religion, pregnancy, and a focus on abstinence. The low-alcohol and alcohol-free beer production is based on physical and biological process. Using some of physical methods, alcohol is removed from regular beer by thermal or membrane-mediated processes. On the other hand, biological methods modify the normal brewing process so that fermentation is limited and almost no ethanol is produced. Biological methods are the most commonly used approach for producing low-alcohol and alcohol-free beer, as additional equipment installation is not necessary to reduce ethanol formation. The definitions of “low-alcohol” and “alcohol-free” vary in different countries, but mostly ethanol content in alcohol-free beer is restricted to 0.5% v/v.

The aim of this study was to evaluate the quality of alcohol-free beer produced from 100% barley malt, with the application of different mashing regimes - standard Congress method and modified mashing regime, as recommended by yeast manufacturer which was used in beer fermentation. Target wort extract content in produced worts was 8.5; 7.5 and 6.5 g/100 g wort. Fermentation was performed with a pure production culture of the yeast *Saccharomyces cerevisiae* var. *chevalieri* (SafBrew™ LA-01), manufactured by Fermentis (Lesaffre, France). The quality assessment of produced beer included: ethanol, real and apparent extract, real and apparent fermentability, pH value, colour, bitterness, and number of yeast cells. According to yeast manufacturer specifications, the selected yeast strain does not exhibit the ability to assimilate maltose. Therefore, the concentration of maltose was determined in all samples of green beers. In worts produced using modified mashing regime a significantly higher ethanol content was determined compared to worts produced using the standard Congress method. By applying the yeast for the fermentation of worts produced using the Congress method, the limit ethanol content for alcohol-free beers was reached on the second day of fermentation, at which point it was stopped. In worts produced with a modified mashing regime, the limit ethanol content was achieved on the first day. In the wort with the highest extract content, the highest concentration of maltose was determined, while the lowest concentration of maltose was found in the wort with the lowest extract content. The applied yeast strain did assimilate maltose during fermentation, although in a small extent.

Key words*: beer, alcohol-free beer, mashing, yeast*

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UTICAJ RAZLIČITIH METODA KOMLJENJA NA TEHNOLOŠKE PARAMETRE BEZALKOHOLNOG PIVA

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Pivo je treće najčešće konzumirano piće, nakon vode i čaja, i najpopularnije alkoholno piće na globalnom nivou. Naučno je dokazano da umerena konzumacija piva ima niz pozitivnih efekata na organizam čoveka, zahvaljujući komponentama ječma (slada) i hmelja, dva neizostavna sastojaka piva. Međutim, ovi zdravstveni benefiti piva ograničeni su negativnim uticajem etanola koji je takođe prisutan u pivu. Kako u poslednje vreme raste interesovanje za zdravlje, uz osvešćivanje ljudi o negativnom dejstvu etanola, potrošači se sve više opredeljuju za piva sa niskim sadržajem alkohola i bezalkoholna piva. Globalna potražnja za niskoalkoholnim i bezalkoholnim napicima je u stalnom porastu usled izmenjenih potrošačkih navika koje se danas usmeravaju ka zdravijem načinu života, strožijih regulacija vezanih za alkohol, religije, trudnoće i apstinencije. Proizvodnja piva sa niskim sadržajem alkohola i bezalkoholnih piva zasniva se na fizičkim i biološkim procesima. Primenom neke od fizičkih metoda, termičkih ili membranskih, etanol se uklanja iz piva koje je proizvedeno na uobičajeni način. Sa druge strane, biološke metode modifikuju uobičajeni proces proizvodnje piva, ograničavajući tako fermentaciju, što za posledicu ima formiranje etanola u veoma malim koncentracijama. Biološke metode više su zastupljene jer ne zahtevaju dodatnu opremu u cilju smanjenja sadržaja etanola. Definicije „piva sa smanjenim sadržajem alkohola“ i „bezalkoholna piva“ razlikuju se u različitim zemljama, ali je uglavnom sadržaj etanola u bezalkoholnim pivima ograničen na 0,5 % v/v.

Cilj ovog rada je ispitivanje kvaliteta bezalkoholnih piva proizvedenih iz 100% ječmenog slada uz primenu različitih metoda komljenja. Za proizvodnju sladovine primenjena je standardna Kongresna metoda, kao i modifikovani režim komljenja, po preporuci proizvođača kvasca koji je korišćen u fermentaciji piva. Ciljani sadržaj ekstrakta u proizvedenim sladovinama je bio 8,5; 7,5 i 6,5 g/100g sladovine. Fermentacije su izvođene s čistom proizvodnom kulturom kvasca *Saccharomyces cerevisiae* var. *chevalieri* (SafBrew™ LA-01), proizvođača Fermentis (Lesaffre, Francuska). Analiza kvaliteta piva je obuhvatala sledeće parametre: etanol, pravi i prividni ekstrakt, pravi i prividni stepen fermentabilnosti, pH vrednost, boju, gorčinu i broj ćelija kvasca. Prema specifikaciji proizvođača kvasca koji je korišćen u fermentaciji sladovine, primenjeni soj kvasca ne pokazuje sposobnost asimilovanja maltoze. Stoga je sadržaj maltoze analiziran u svim uzorcima mladog piva. U sladovinama koje su proizvedene modifikovanom metodom komljenja određen je značajno viši sadržaj etanola u poređenju sa sladovinama koje su proizvedene standardnom Kongresnom metodom. Fermentacijom sladovina koje su proizvedene standardnom Kongresnom metodom granični sadržaj etanola za bezalkoholna piva dostignut je drugog dana fermentacije, kada je fermentacija i zaustavljena. U sladovinama proizvedenim modifikovanim režimom komljenja granični sadržaj etanola dostignut je prvog dana fermentacije. Sladovine sa najvećim sadržajem ekstrakta imale su najveću koncentraciju maltoze, dok je u sladovinama sa najnižim sadržajem ekstrakta određena najmanja koncentracija maltoze. Primenjeni soj kvasca asimilovao je maltozu tokom fermentacije, iako u maloj količini.

***Ključne reči**: pivo, bezalkoholno pivo, komljenje, pivski kvasac*

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FUTURE TRENDS AND LIMITATIONS OF ESSENTIAL OILS AND PLANT EXTRACTS AS ADDITIVES IN THE FORMULATION OF EDIBLE PACKAGING

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Edible packaging is most commonly used in the form of films or coatings that cover various types of food to extend shelf life and serve as carriers of bioactive compounds that promote human health. Additionally, edible films and coatings can serve as sustainable alternatives to commercial plastic packaging, which poses both environmental and health concerns. These formulations primarily rely on natural hydrocolloids, including polysaccharides such as pectin, starch, alginate, and carrageenan; proteins like collagen, casein and gelatin; and lipids and waxes. One of the key advantages of edible films and coatings is their ability to incorporate active compounds (e.g., antimicrobials, antioxidants, nutraceuticals, flavors, colors) into polymer matrices. Essential oils and plant extracts are among the most valuable naturally derived ingredients due to their antimicrobial, antioxidant and antifungal properties, attributed to their bioactive compounds. As a result, the food industry has recognized them not only as natural preservatives but also as agents for enhancing the aroma and taste of foods. According to literature data, plant extract incorporation into edible packaging has been successfully implemented; however, the resulting films often exhibit undesirable properties, such as structural instability, reduced elasticity and break resistance, lower transparency and gloss, and diminished effectiveness. Additionally, using essential oils and plant extracts in larger-than-necessary quantities to achieve antimicrobial and antioxidant effects may negatively impact the organoleptic properties of packaged foods. Significant losses of volatile compounds have also been observed during the drying phase of edible films and coatings. To mitigate this, essential oils and plant extracts have been incorporated in the form of nanoemulsions. Encapsulation in nanoemulsions has been shown to enhance stability and minimize strong flavors and odors. However, before these agents are introduced into the food chain, appropriate safety assessments and toxicological studies must be conducted.

***Key words**: edible packaging, essential oils, plant extracts, nanoemulsion.*

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BUDUĆI TRENDOVI I OGRANIČENJA ETERIČNIH ULJA I BILJNIH EKSTRAKATA KAO ADITIVA U FORMULACIJI JESTIVE AMBALAŽE

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Jestiva ambalaža najčešće se koristi u obliku folija ili premaza kojima se prekrivaju različite vrste hrane kako bi se produžio rok trajanja i služila kao prijenosnik bioaktivnih spojeva koji promiču ljudsko zdravlje. Osim toga, jestive folije i premazi mogu poslužiti kao održiva alternativa komercijalnoj plastičnoj ambalaži, koja predstavlja brigu za okoliš i zdravlje. Ove se formulacije primarno oslanjaju na prirodne hidrokoloide, uključujući polisaharide poput pektina, škroba, alginata i karagenana; proteine poput kolagena, kazeina i želatine; te lipide i voskove. Jedna od ključnih prednosti jestivih filmova i premaza njihova je sposobnost ugradnje aktivnih spojeva (npr. antimikrobnih sredstava, antioksidansa, nutraceutika, aroma, boja) u polimerne matrice. Eterična ulja i biljni ekstrakti među najvrjednijim su sastojcima prirodnog podrijetla zbog svojih antimikrobnih, antioksidativnih i antifungalnih svojstava, koja se pripisuju njihovim bioaktivnim spojevima. Zbog toga ih je prehrambena industrija prepoznala ne samo kao prirodne konzervanse, već i kao sredstva za poboljšanje arome i okusa hrane. Prema literaturnim podacima uspješno je provedena ugradnja biljnih ekstrakata u jestivu ambalažu; međutim, dobiveni filmovi često pokazuju nepoželjna svojstva, kao što je strukturna nestabilnost, smanjena elastičnost i otpornost na lomljenje, manja prozirnost i sjaj, te smanjena učinkovitost. Osim toga, korištenje eteričnih ulja i biljnih ekstrakata u količinama većim od potrebnih za postizanje antimikrobnih i antioksidativnih učinaka može negativno utjecati na organoleptička svojstva pakirane hrane. Također su primijećeni značajni gubici hlapljivih spojeva tijekom faze sušenja jestivih filmova i premaza. Kako bi se to ublažilo, eterična ulja i biljni ekstrakti ugrađeni su u obliku nanoemulzija. Pokazalo se da inkapsulacija u nanoemulzijama poboljšava stabilnost i smanjuje jake okuse i mirise. Međutim, prije nego što se ti agensi uvedu u prehrambeni lanac, moraju se provesti odgovarajuće procjene sigurnosti i toksikološke studije.

Ključne riječi: *jestiva ambalaža, eterična ulja, biljni ekstrakti, nanoemulzija.*

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THE STRUCTURE OF THE PROTEIN CONCENTRATE OBTAINED BY THE ULTRASONIC AND CHEMICAL DEPROTEINIZATION PROCESS OF THE SPINY CRAYFISH SHELL FROM THE DANUBE RIVER

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The invasive species of river crayfish Faxonius limosus, which has a significant negative impact on the biodiversity of rivers in which it overproliferates, endangering other species of crayfish and fish, has been detected in Serbia throughout the entire course of the Danube, as well as the Sava, Tisa, Tamiš and Velika Morava rivers. One possible approach to controlling this problem is to catch individuals of the spiny cheek crayfish in order to use their meat for human consumption. When the crayfish meat is removed, a large amount of shell remains, which can be a source of highly valuable components, such as chitin, chitosan, protein, astaxanthin and others.

The usual and most commonly used method of extracting protein from crayfish shells is the use of strong base baths at elevated temperatures. This method has proven to be effective, but its main drawback is the use of a significant amount of strong base. As a green alternative to this extraction method, extraction using ultrasound in water, at room temperature, has been proposed.

In this paper, the structure of protein concentrate isolated by chemical and ultrasonic deproteinization processes is compared. The analysis of the amino acid composition indicated a slightly higher total content of amino acids in the case of the classic chemical method of isolation, whereby this difference mainly comes from the content of essential amino acids. Non-polar amino acids dominate over polar amino acids in both concentrates (three times higher), while the ratio of hydrophilic and hydrophobic amino acids is different in these two concentrates. Namely, the chemically obtained concentrate has a uniform ratio of hydrophilic and hydrophobic amino acids, while in the case of the ultrasonic concentrate, this ratio is in favor of the hydrophilic ones. Of all amino acids, the highest content was found for aspartic and glutamic acids, followed by leucine and phenylalanine in the chemical concentrate, and leucine and lysine in the ultrasonic concentrate.

FTIR analysis of the spectrum of protein concentrates revealed peaks typical for proteins, amide I (1700–1600 cm^{-1}), amide II (1600–1500 cm^{-1}) and amide III (1300–1200 cm^{-1}). By analyzing the shape and position of the amide peaks, as well as by deconvolution of the amide I peak, an assessment of the secondary structure of the protein in the protein concentrate was obtained. In both concentrates, the most abundant conformation is random. In the case of the chemical concentrate, the β-sheet follows and then the α-helix, while in the case of the UV concentrate, these conformations are equally represented. The more well-preserved and ordered structure of the UV concentrate may be a consequence of the lower temperature and the absence of chemicals during extraction.

The obtained protein concentrates can represent an additional valorization of the shell of the river crayfish and have a significant application for animal feed or for obtaining biodegradable packaging, or edible casings for food or feed products.

Key words: *protein concentrate, river crayfish, FTIR, conformation, amino-acid content*

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STRUKTURA PROTEINSKOG KONCENTRATA DOBIJENOG ULTRAZVUČNIM I HEMIJSKIM POSTUPKOM DEPROTEINIZACIJE LJUŠTURE BODLJOBRADOG REČNOG RAKA IZ REKE DUNAV

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Invazivna vrsta rečnog raka Faxonius limosus, koja umnogome negativno utiče na biodiverzitet reka u kojima se prenamnoži ugrožavajući ostale vrste rakova, ali i riba, detektovan je u Srbiji već u celom toku reke Dunav, ali i Save, Tise, Tamiša i Velike Morave. Jedan od mogućih pristupa da se ovaj problem stavi pod kontrolu je i izlovljavanje jedinki bodljobradog raka radi upotrebe njegovog mesa za ishranu ljudi. Kada se meso raka ukloni, ostaje velika količina ljušture koja može biti izvor visokovrednih komponenata, kao što su hitin, hitozan, protein, astaksantin i drugo.

Klasičan i najčešće upotrebljavan način ekstrakcije proteina iz ljušture rečnog raka je upotreba kupki jake baze, uz povišenu temperaturu. Ova metoda se pokazala efikasnom, ali joj je glavni nedostatak upotreba značajne količine jake baze. Kao zelena alternative ovom načinu ekstrakcije, ponuđena je ekstrakcija primenom ultrazvuka u vodi, pri sobnoj temperature.

U ovom radu je poređena struktura proteinskog koncentrata izolovanog hemijskim i ultrazvučnim procesom deproteinizacije. Analiza aminokiselinskog sastava je ukazala na nešto veći ukupni sadržaj aminokiselina kod klasičnog hemijskog načina izolacije, pri čemu ova razlika pretežno potiče od sadržaja esencijalnih aminokiselina. Nepolarne aminokiseline dominiraju nad polarnim kod oba koncentrata (trostruko više), dok je odnos hidrofilnih i hidrofobnih različit kod ova dva koncentrata. Naime, hemijski dobijen koncentrat ima ujednačen odnos hidrofilnih i hidrofobnih aminokiselina, dok je kod ultrazvučnog koncentrata, ovaj odnos u korist hidrofilnih. Od svih amino kiselina, najveći sadržaj je asparaginske i glutaminske kiseline, a zatim slede leucin i fenilalanin kod hemijskog izolata, a leucin i lizin kod ultrazvučnog koncentrata.

FTIR analizom spektara proteinskih koncentrata, detektovani su pikovi svojstveni za proteine, amid I (1700–1600 cm^{-1}), amid II (1600–1500 cm^{-1}) i amid III (1300–1200 cm^{-1}). Analizom oblika i položaja amidnih pikova, kao i dekonvolucijom amid I pika, dobijena je procena sekundarne strukture proteina u proteinskom koncentratu. Kod oba koncentrata, najzastupljenija konformacija je “random”. Za njom, kod hemijskog koncentrata sledi “β-sheet”, pa “α-heliks”, dok su kod UV koncentrata ove konformacije podjednako zastupljene. Očuvanija uređenija struktura kod UV koncentrata može biti posledica niže temperature i odsustva hemikalija prilikom ekstrakcije.

Dobijeni proteinski koncentrati mogu predstavljati dodatnu valorizaciju ljušture rečnog raka i imati značajnu primenu za hranu za životinje ili za dobijanje biorazgradive ambalaže, ili jestivih omotača za prehrambene proizvode.

***Ključne reči**: proteinski koncentrat, rečni rak, FTIR, konformacija, aminokiselinski sastav*

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EFFECT OF HIGH-PRESSURE TREATMENTS ON THE QUALITY AND SHELF-LIFE OF AN ORANGE-BERGAMOT BEVERAGE

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Citrus-based beverages are widely appreciated for their refreshing flavor, nutritional value, and high content of bioactive compounds. However, their quality and shelf-life can be significantly affected by microbial spoilage and physicochemical degradation during storage. High-pressure treatments, such as High-Pressure Homogenization (HPH) and High Hydrostatic Pressure (HHP), have emerged as promising non-thermal technologies that preserve the sensory and nutritional attributes of food products while ensuring microbiological safety. In this context, this study evaluates the impact of high-pressure treatments, specifically HPH and HHP, on the quality and shelf-life of an innovative orange-bergamot beverage during refrigerated storage. The shelf-life assessment involved monitoring microbiological stability, antioxidant activity, volatile molecule profiles, pH, color stability, and total phenolic compounds (TPC) over 19 days at 4°C and under thermal abuse conditions at 8°C. Untreated juice served as the control, with comparisons also made to pasteurized juice.

Both hyperbaric treatments—HPH at 200 MPa for 3 cycles and HHP at 600 MPa for 100 seconds—along with thermal treatment at 80°C for 15 minutes, maintained microbiological stability for 19 days at 4°C and 8°C, whereas untreated samples spoiled after 13 days at 8°C. A challenge test with Hanseniapora occidentalis and Lactiplantibacillus plantarum confirmed that hyperbaric treatments reduced the cell load of the inoculated microorganisms by more than five logarithmic cycles. HHP and HPH samples demonstrated superior preservation of volatile profiles, color, and antioxidant activity compared to other samples, which exhibited deteriorations over time. In conclusion, HHP and HPH treatments offer an effective alternative to thermal pasteurization for preserving bioactive compounds, antioxidant activity, and volatile profiles, while extending the shelf-life of citrus juices.

***Key words**: Citrus beverage, high pressure homogenization, high hydrostatic pressure, microbiological stability, shelf-life, functionality*

DIVERSIFIYING ROSES FOR 21st CENTURY'S ENVIRONMENTAL AND SOCIAL NEEDS

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This study assessed 11 distinctive collections from 'Pheno Geno Roses' breeding company. Predominantly created to meet landscaping purposes, vibrant 'Fashion,' 'Freska,' 'Abundant Reka,' and 'Art Vaza' collections showcase ornamental roses with vigorous growth, prolific blooms, and moderate disease resistance. The aromatic 'The Sense of Love' and 'Frayla' collections stand out for their captivating fragrances, stemming from high levels of volatile compounds. For gardens with an edible touch, the 'Taste of Love' and 'Aurora' collections feature roses that produce fruits suitable for fresh consumption or processing. Meanwhile, the sound-enhancing 'Mella' collection draws bees and pollinators, creating a lively buzz around the bushes. Compact and adaptable, the 'Pixie' collection offers patio roses perfect for container gardening, whether in large terracotta pots or small windowsill containers, catering to urban gardening needs. Finally, the resilient 'Winterjewel' collection, developed using advanced breeding techniques, thrives in extreme cold, withstanding temperatures as low as −35 °C. Despite their hardiness, these roses exhibit remarkable health, diverse colors, repeat blooming, and a delicate yet enduring appearance. Our results further proved that those roses represent a versatile resource for advancing the circular bioeconomy due to their diverse potential applications in bioliquids, biopesticides, and bio-based (biodegradable) bioplastic's and biofilm's products development. This study explores the potential of rose-derived oils, phenolic compounds, and biomass residues for sustainable applications. The seeds of species such as Rosa moschata, Rosa canina, and Rosa rubiginosa contain high oil content, while yields from 'Pheno Geno Roses' reached 5.2%, potentially suitable for both cosmetics and bioliquids production. Furthermore, phenolic-rich extracts from rose petals and leaves demonstrated significant bioactivity, with antioxidant capacities up to 15.78 µg/mL (IC50 value in DPPH assay), and up to 227 mg AAE/g de in FRAP assay. Also, rose extracts have possible insecticidal efficacy against aphids. Namely, several genotypes from mentioned breeding program expressed considerable quantities of protocatechuic and gallic acids ranging from 11.1 to 44.8 µg/g de. Furthermore, essential oils extracted from rose genotypes contained bioactive compounds such as neral, geranial, geraniol, citronellol, and eugenol, with proven pesticide activity or pest repellence efficacy. Our findings highlight roses as a promising feedstock for integrated processing facilities, enabling the production of bioliquids, natural biopesticides, and bio-based materials while minimizing waste. By fully utilizing rose biomass, this research contributes to sustainable agricultural practices and the development of eco-friendly alternatives to synthetic products, fostering a circular bioeconomy.
***Key words**: green chemistry, nature-based solutions, ornamental horticulture, rose germplasm, sustainability*

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DIVERZIFIKACIJA RUŽA ZA EKOLOŠKE I DRUŠTVENE POTREBE 21. VEKA

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Ova studija obuhvatila je procenu 11 jedinstvenih kolekcija ruža iz programa oplemenjivačke kompanije 'Pheno Geno Roses'. Pretežno kreirane za pejzažno ozelenjavanje, dekorativne kolekcije 'Fashion,' 'Freska,' 'Abundant Reka' i 'Art Vaza' ističu se ukrasnim ružama snažnog rasta, obilnog cvetanja i umerene otpornosti na bolesti. Aromatične kolekcije 'The Sense of Love' i 'Frayla' izdvajaju se svojim očaravajućim mirisima, zahvaljujući visokim nivoima isparljivih jedinjenja. Za dekorativne bašte praćene jestivim dodirom, kolekcije 'Taste of Love' i 'Aurora' nude ruže koje daju plodove pogodne za svežu upotrebu ili preradu. U međuvremenu, kolekcija 'Mella' privlači pčele i oprašivače, stvarajući živahnu atmosferu oko biljaka. Kompaktna i prilagodljiva, kolekcija 'Pixie' pruža ruže za terase, savršene za uzgoj u saksijama, bilo u velikim terakota posudama ili malim prozorskim posudama, zadovoljavajući potrebe urbanog baštovanstva. Na kraju, otporna kolekcija 'Winterjewel,' razvijena korišćenjem naprednih uzgojnih tehnika, uspeva u ekstremnim hladnoćama, podnoseći temperature do −35 °C. Uz izraženu izdržljivost, ove ruže pokazuju izuzetan kvalitet, raznolike boje, ponavljajuće cvetanje i nežan, ali trajan izgled. Rezultati ovog istraživanja dodatno su potvrdili da ispitivane ruže predstavljaju svestran resurs za unapređenje cirkularne bioekonomije zahvaljujući svojim raznovrsnim potencijalnim primenama u razvoju biotečnosti, biopesticida i bio-baziranih (biorazgradivih) proizvoda poput bioplastike i biofilmova. Studija istražuje potencijal ulja, fenolnih jedinjenja i biomase dobijene iz ruža za šire održive primene. Semena vrsta kao što su Rosa moschata, Rosa canina i Rosa rubiginosa sadrže visok sadržaj ulja, dok je prinos genotipova 'Pheno Geno Roses' dostigao 5,2%, što ih čini pogodnim za proizvodnju kozmetike i biotečnosti. Pored toga, ekstrakti bogati fenolima iz latica i listova ruža pokazali su značajnu bioaktivnost, sa antioksidativnim kapacitetima do 15,78 μg/mL (IC50 vrednost u DPPH testu) i do 227 mg AAE/g de u FRAP testu. Ekstrakti ruža takođe pokazuju moguću insekticidnu efikasnost protiv lisnih vaši. Naime, nekoliko genotipova iz pomenutog oplemenjivačkog programa sadržalo je značajne količine protokatehinske i galne kiseline u rasponu od 11,1 do 44,8 μg/g de. Takođe, esencijalna ulja izdvojena iz genotipova ruža sadržala su bioaktivna jedinjenja poput nerala, geranijala, geraniola, citronelola i eugenola, sa dokazanom pesticidnom aktivnošću ili efikasnošću u odbijanju štetočina. Dobijeni rezultati ističu ruže kao obećavajuću sirovinu za integrisana postrojenja za preradu, omogućavajući proizvodnju biotečnosti, prirodnih biopesticida i bio-baziranih materijala uz minimizaciju otpada. Potpunim iskorišćavanjem biomase ruža, ovo istraživanje doprinosi održivim poljoprivrednim praksama i razvoju ekološki prihvatljivih alternativa sintetičkim proizvodima, podržavajući cirkularnu bioekonomiju.

Ključne reči: *genetički resursi ruža, zelena hemija, rešenja zasnovana na prirodi, održivost, ornamentalna hortikultura*

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PIVOT PROFILE METHOD IN SENSORY EVALUATION OF CHICKEN BREAST

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This study aimed to explore the application of the Pivot Profile method in sensory analysis of commercially available chicken breast samples, using free description to capture judges' sensory perceptions and assess the method's effectiveness in generating sensory product profiles. The study was conducted as part of the 'Rapid Methods of Sensory Profiling' workshop at the Institute for Food Technology in Novi Sad, Serbia, with participants from various sectors of the industry, including representatives from the meat sector.
A total of 20 participants evaluated the samples, using sample CB7 as a reference (pivot). Six commercially available chicken breast samples (CB1–CB6) were presented in a random order. For each sample, participants paired it with the pivot and recorded all perceived attributes in relation to the pivot using free description. The data were then organized into a chicken-breast-attributes matrix and analysed using Correspondence Analysis to generate a product map. All attributes were included in the analysis, with only a few showing low citation frequencies. The analysis was conducted using the XLSTAT software package (version 2023.3.1, Addinsoft, New York, NY, USA).
The results from applying the Pivot Profile method to the chicken breast samples provided valuable insights into the relationships between the attributes and their contribution to the overall variability of the samples. Although the attributes were found to be independent, with a low degree of interdependence, significant factors such as colour ('yellowish') and texture ('tender_MF') played a key role in driving data variation. The first two principal components (F1 and F2) accounted for over 50% of the variability between the samples, highlighting their importance in distinguishing differences among the samples. Attributes such as 'aromatized_F' and 'bitter' were less significant, while colour and texture emerged as dominant attributes in the analysis.
These findings suggest that, despite the separation of attributes, further research is needed to better understand their interrelationships and improve the accuracy of chicken breast evaluations, particularly in the context of quality control and sensory profiling. This method could improve the understanding of key quality characteristics that influence consumer preferences and product consistency, such as chicken breast. Furthermore, a practical case study using chicken breast demonstrated that the Pivot Profile method is easy for participants to apply and facilitates the creation of meaningful product descriptions.
***Key words**: rapid sensory method, chicken breast, pivot profile*

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PIVOT PROFILE METOD U SENZORSKOJ OCJENI PILEĆIH PRSA

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Ova studija imala je za cilj istraživanje primjene metode Pivot Profile u senzorskoj analizi komercijalno dostupnih uzoraka pilećih prsa, koristeći slobodan opis za zabilježavanje senzorskih opažanja sudija i procjenu efikasnosti metode u generiranju senzorskih profila proizvoda. Studija je sprovedena kao dio radionice „Brze metode senzorskog profiliranja“ na Naučnom institutu za prehambene tehnologije u Novom Sadu, Srbija, sa učesnicima iz različitih sektora industrije, uključujući predstavnike mesne industrije.
Ukupno 20 učesnika ocjenjivalo je uzorke, koristeći uzorak CB7 kao referencu (pivot). Šest komercijalno dostupnih uzoraka pilećih prsa (CB1–CB6) predstavljeno je u slučajnom redoslijedu. Za svaki uzorak, učesnici su ga usporedili sa pivotom i zabilježili sve opažene atribute u odnosu na pivot koristeći slobodan opis. Podaci su zatim organizirani u matricu atributa pilećih prsa i analizirani pomoću analize povezivanja (*Correspondence Analysis*) kako bi se generisala mapa proizvoda. Svi atributi su uključeni u analizu, a samo nekoliko njih imalo je nisku učestalost citiranja. Analiza je sprovedena pomoću softverskog paketa XLSTAT (verzija 2023.3.1, Addinsoft, New York, NY, SAD).
Rezultati primjene metode Pivot Profile na uzorcima pilećih prsa pružili su vrijedne uvide u međusobne odnose između atributa i njihov doprinos ukupnoj varijabilnosti uzoraka. Iako su atributi pronađeni kao nezavisni, sa niskim stepenom međuzavisnosti, značajni faktori poput boje („žutkasta“) i teksture („mekoća_MF“) igrali su ključnu ulogu u pokretanju varijacije podataka. Prve dvije glavna komponenta (F1 i F2) obuhvatila su više od 50% varijabilnosti između uzoraka, što je naglasilo njihov značaj u razlikovanju razlika među uzorcima pilećih prsa. Atributi poput „aromatizovan_F“ i „gorko“ bili su manje značajni, dok su boja i tekstura nastali kao dominantni atributi u analizi.
Ovi nalazi sugerišu da, uprkos razdvajanju atributa, dalja istraživanja su potrebna kako bi se bolje razumjeli njihovi međusobni odnosi i poboljšala tačnost ocjenjivanja pilećih prsa, posebno u kontekstu kontrole kvaliteta i senzorskog profilisanja. Ova metoda bi mogla poboljšati razumijevanje ključnih karakteristika kvaliteta koje utiču na potrošačke preferencije i dosljednost proizvoda, kao što su pileća prsa. Dodatno, praktična studija slučaja koja koristi pileća prsa pokazala je da je metoda Pivot Profile laka za primjenu od strane učesnika i olakšava kreiranje značajnih opisa proizvoda.
Ključne reči: *brzi senzorski metod, pileća prsa, pivot profile*

THE FUTURE OF A BIOGAS IN SERBIA

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The biogas plant uses biogas as its main energy source, which is basically a mixture of combustible and non-combustible gases. It is produced by anaerobic fermentation of organic matter. Anaerobic fermentation is the process of decomposition (rotting) of organic matter without the presence of air, i.e. without the presence of oxygen. Besides the fact that the process is anaerobic, it is also mesophilic and takes place at around 43°C. Biogas is the fuel for the SUS engine which is connected to the generator (CHP) by a shaft. As an output product, the biogas plant generates two forms of energy - electrical and thermal, as well as high-quality organic fertilizer, i.e. post-fermentation residue, which, if separated, is divided into liquid and solid phases. The first plants of this type in Serbia started operating at the end of 2011 and at the beginning of 2012, and according to the then Law on Energy, i.e. the Decree on the conditions for obtaining the status of a privileged producer of electricity, they signed a contract on the purchase of electricity under the so-called feed-in conditions for 12 years. Put into operation in 2012, the first plants had to "break the ice", paving the way for all of us who work in the sector today, while proving that biogas is not only an effective solution for organic waste management, but also a guardian of the environment, health, nature and communities. The operators behind these facilities faced mistrust, skepticism, as well as unfounded and wrong narratives, because the community was largely unprepared for the technology, which seemed like "rocket science" at the time. The first biogas operators had to prove a lot, both to the authorities and to the community - first of all, that such plants are completely safe and that accidents are not possible with proper handling. Biogas production is a strictly controlled process, which the following years have confirmed. In addition, they proved that they stabilize the electricity grid, because they work in a 24/7 mode, and that the production of electricity from biogas is a completely predictable process (although the opposite was believed). Those plants are considered pioneers who laid the foundation for renewable energy from biogas in Serbia. These plants were not only a technological endeavor, but symbols of hope and proof that Serbia can make a step towards a sustainable future. Behind them stood visionaries, people ahead of their time, ready to face challenges and the unknown. They knew that the road would not be easy, but they believed in the power of this innovation and in the profession that would recognize its value. At the end of 2019, the Regulation on incentive measures for the production of electricity from renewable sources ceases to be valid, and the adoption of a new Regulation has been long awaited. It was finally adopted in 2023, but under new conditions, where the feed-in system is no longer valid. Also, the plants that signed the Agreements in 2012 and whose 12-year Agreements have expired are also falling into oblivion. While a group of experts and enthusiasts fight to preserve these pioneers, we face a wall of bureaucracy and misunderstanding. Although the sector is developing, the symbolism of these plants must not be forgotten. Two of the three pioneering plants have already been shut down, left as concrete structures in a meadow – symbols of avoidable failure. After the contract with EPS expired, they did not receive any support from the state and were left to decay. This is not only a loss for the sector, but also for all of us who believe in this technology, in progress and in the right to clean air and water. While we face environmental challenges, we let biogas plants, which offer solutions for the disposal of huge amounts of organic waste (30-100t per day per installed MW), to decay. The competent Ministry does not consider their further status and potential survival, although we all know their importance for the living environment, as well as for the very stability of the electricity system. Biomethane, which, along with the disposal of biological, non-hazardous waste, is a potential future and the path by which these plants, as well as some of the next ones, could potentially start, is still a general unknown in our country, although it has been in use in Europe for more than 10 years. This is not only an issue of the energy sector and the competent ministry, but also of the agriculture sector, as well as ecology, and it is necessary to strengthen and support the further survival and development of the sector, which is on the verge of existence, through joint action. These plants are a real model of the circular economy in practice, because they show how we can reduce the amount of waste, produce energy and contribute to sustainable development. Furthermore, there is no other residue left from this process (except high-quality fertilizer) and this is a fully rounded process. Unfortunately, despite everything that seems logical and sustainable, the biogas sector in Serbia faces major challenges. Although we have an abundance of organic waste, its cost is often prohibitive and its availability limited. Why? Because many waste generators still choose an easier and cheaper solution. Furthermore, the lack of incentives and adequate mechanisms further aggravates the situation.

***Key words**: biogas, renewable energy, green energy, development*

BUDUĆNOST BIOGASA U SRBIJI

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Biogasno postrojenje kao svoj osnovni energent koristi biogas, koji je u osnovi mešavina gorivih i negorivih gasova. On nastaje anaerobnom fermentacijom organskih materija. Anaerobna fermentacija predstavlja proces razlaganja (truljenja) organske materije bez prisustva vazduha, odnosno bez prisustva kiseonika. Osim što je process anaeroban, on je i mezofilan i odigrava se na oko 43°C. Biogas je pogonsko gorivo za SUS motor koji je vratilom povezan sa generatorom(CHP). Kao izlazni proizvod, biogasno postrojenje generiše dva oblika energije – električnu i toplotne, kao i visokokvalitetno organsko djubrivo, odnosno postfermentorski ostatak, koji se, ukoliko se separiše, deli na tečnu i čvrstu fazu. Prva postrojenja ovakvog tipa u Srbiji su počela sa radom krajem 2011. i početkom 2012. godine i po tadašnjem Zakonu o Energetici, odnosno Uredbi o uslovima za sticanjem statusa povlašćenog proizvodjača električne energije potpisali su Ugovor o otkupu električne energije po tzv feed in uslovima na 12 godina. Puštena u rad 2012. godine, prva postrojenja su morala da "probijaju led", utirući put svima nama koji danas radimo sektoru, istovremeno dokazujući da biogas nije samo efikasno rešenje za upravljanje organskim otpadom, već i čuvar životne sredine, zdravlja, prirode i zajednica. Operateri koji su stajali iza ovih postrojenja, suočavali su se sa nepoverenjem, skepticizmom, kao i neutemeljenim i pogrešnim narativima, jer zajednica mahom nije bila spremna za tehnologiju koja se tada delovala kao"raketna nauka". Prvi biogas operateri su morali da dokazuju, kako nadležnima, tako i zajednici puno toga – pre svega da su ovakva postrojenja potpuno bezbedna i da havarije nisu moguće uz pravilno rukovanje. Proizvodnja biogasa je strogo kontrolisan proces, što su godine koje su usledile i potvrdile. Osim toga, dokazivala su da stabilizuju elektro mrežu, jer rade u režimu 24/7, i da je proizvodnja električne energije iz biogasa potpuno predvidljiv proces (iako se verovalo upravo suprotno). Ta postrojenja smatraju se pionirima koji su postavila temelj obnovljive energije iz biogasa u Srbiji. Ova postrojenja nisu bila samo tehnološki poduhvat, već simboli nade i dokaz da Srbija može napraviti iskorak ka održivoj budućnosti. Iza njih su stajali vizionari, ljudi ispred svog vremena, spremni na suočavanje sa izazovima i nepoznatim. Znali su da put neće biti lak, ali su verovali u snagu ove inovacije i u struku koja će prepoznati njenu vrednost. Krajem 2019. godine, Uredba o podsticajnim merama za proizvodnju električne energije iz obnovljivih izvora prestaje da važi i dugo se čekalo na donošenje nove Uredbe. Ona je doneta konačno 2023. godine, ali po novim uslovima, gde "feed in" sistem više ne važi. Takođe, padaju u zaborav i postrojenja koja su ugovore potpisali 2012. godine i kojima su ugovori od 12 godina istekli. Dok se grupa stručnjaka i entuzijasta, bori da sačuva ove pionire, suočavamo se sa zidom birokratije i nerazumevanja. Iako se sektor razvija, simbolika ovih postrojenja ne sme biti zaboravljena. Dva od tri pionirska postrojenja su već ugašena, ostavljena kao betonske konstrukcije na livadi – simboli neuspeha koji se mogao izbeći. Nakon isteka ugovora sa EPS-om, nisu dobila nikakvu podršku države i prepuštena su propadanju. Ovo nije samo gubitak za sektor, već i za sve nas koji verujemo u ovu tehnologiju, u napredak i u pravo na čist vazduh i vodu. Dok se suočavamo sa ekološkim izazovima, prepuštamo biogas postrojenja, koja nude rešenja za zbrinjavanje ogromne količine organskog otpada (30-100 t dnevno po instalisanom MW), da propadaju. Nadležno Ministarstvo ne razmatra njihov dalji status i potencijalni opstanak iako svi znamo njihov značaj i po životnu okolinu, kao i po samu stabilnost elektgroenergetskog sistema. Biometan, koji je uz zbrinjavanje biološkog, neopasnog otpada, potencijalna budućnost i put kojim bi potencijalno, ova postrojenja, ali i neka sledeća mogla da pođu, još uvek je kod nas opšta nepoznanica, iako je u Evropi u primeni više od 10 godina. Ovo nije pitanje samo energetskog sektora i nadležnog ministarstva, nego i sektora poljoprivrede, kao i ekologije i potrebno je zajedničkim delovanjem osnažiti i podržati dalji opstanak i razvoj sektora, koji je na rubu egzistencije. Biogasna postrojenja nude rešenje koje ne samo da efikasno rešava problem otpada, već, u biogas postrojenju organski otpad dobija ekonomsku vrednost, u vidu korisnih oblika energije – električne, toplotne i biometana, kao i visokokvalitetnog đubriva. Ova postrojenja su pravi model cirkularne ekonomije u praksi, jer pokazuju kako možemo smanjiti količinu otpada, proizvesti energiju i doprineti održivom razvoju. Štaviše, iz ovog procesa ne ostaje ni jedan drugi ostatak (osim visokokvalitetnog đubriva) i ovo je jedan potpuno zaokružen proces. Nažalost, i pored svega što se čini logičnim i održivim, sektor biogasa u Srbiji suočava se sa velikim izazovima. Iako imamo obilje organskog otpada, njegova cena je često previsoka, a dostupnost ograničena. Zašto? Zato što mnogi generatori otpada i dalje biraju lakše i jeftinije rešenje. Dalje, nedostatak stimulacija i adekvatnih mehanizama dodatno pogoršava situaciju.

Ključne reči – *biogas, obnovljivi izvori, zelena energija, razvoj*

FULL CHARACTERIZATION OF CHITOSAN, RESULTING FROM THE VALORISATION OF FISH WASTE, TO BE USED FOR THE FORMULATION OF BIOSTIMULANTS

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Seafood waste contains several added value compounds which are under-exploited and poorly used such as chitosan or collagen. Currently, chitosan and collagen extractions are performed mainly by hydrolysis and heat treatments, that require high volumes of solvents, long times, and are characterised by low yields. In addition, the complexity and composition variability of the feedstock can compromise the efficiency of extraction processes. A novel train of technologies composed by non-thermal technologies like pulsed electric field (PEF), high hydrostatic pressure (HHP), and/or ultrasounds (US) combined with biotechnological processes have been tested for maximizing the extraction yield of biopolymers such as chitosan and collagen, from crustaceous wastes and fish skin. Thus, within ReLEAF project (GA n. 101156998) several green approaches have been tested, starting from exoskeleton of mantis shrimp, to extract chitosan. The obtained biopolymer was characterized in terms of average molecular weight, FT-IR spectroscopy, differential scanning calorimetry (DSC) measurements, water holding capacity, oil holding capacity, yield and color in comparison to commercially available products. Moreover, since the final aim of ReLEAF project is to produce microbial biostimulants using chitosan as entrapping material, the obtained biopolymer was tested, with microtiter approaches, for its antimicrobial properties against a wide gamma of bacteria potentially exploitable as Plant Growth Promoting Bacteria (PGPB). The used approach, optimized at lab scale, permitted to obtain a biopolymer with high molecular weight and a degree of deacetylation of ≥75%, that should be advantageous for cold extrusion of chitosan, since these properties could contribute to the material's processability. Moreover, according to the percentage used, chitosan exhibited different antimicrobial activities in relation to employed microbial strains. The collected information will be useful to set-up properly the final biostimulant formulation and for choose the proper microbial strain.

***Key words**: Chitosan, fish waste, Plant Growth Promoting Bacteria, biostimulants, antimicrobial properties*

SENSORY LEXICON FOR FROZEN ARILJE RASPBERRIES

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The aim of this study was to develop a sensory lexicon for frozen Arilje raspberries, focusing on key sensory attributes. Sensory analysis was performed by a trained panel of 19 assessors on eight frozen raspberry samples cultivated in different regions of Serbia. The samples included three raspberry varieties from Arilje (Miker, Vilamet, and Enrosadira), as well as varieties from other locations: Miker from Bačka Palanka, Tulamin from Đurđevo, Polana from Bečej, and two commercial samples (Premia and Frikom) without specific variety labelling. The sensory analysis was carried out at the Institute of Food Technology in Novi Sad, using 52 descriptors rated on a 5-point scale. To assess and quantify sensory differences, the study applied the Rate-All-That-Apply (RATA) methodology, which is particularly useful in sensory evaluations of food products.

Analysis of variance (ANOVA) revealed significant differences in sensory attributes among the frozen raspberry varieties, with Arilje raspberries (Miker, Vilamet, and Enrosadira) being rated higher in key attributes such as flavour balance, juiciness, texture consistency, and overall aroma. The Arilje varieties exhibited superior uniformity in fruit size and shape, which contributed to their higher sensory ratings compared to other regional and commercial samples. In contrast, some other varieties, such as Polana and Tulamin, showed variability in fruit size, shape, and flavour, with some exhibiting undesirable metallic or bitter notes.

Principal component analysis (PCA) further supported these findings. The first three principal components (PC1, PC2, and PC3) accounted for 36.42%, 19.23%, and 14.75% of the total variance, respectively, resulting in a cumulative variance of 70.40%. PC1 was strongly associated with attributes such as small fruit size and metallic off-flavour, clearly distinguishing the Polana (Bečej) variety, which scored high on these attributes, from Miker (Arilje), which displayed a more balanced combination of sensory characteristics. PC2 primarily related to shape and consistency after freezing, where Vilamet (Arilje) showed higher visual consistency compared to Tulamin (Đurđevo), which had more inconsistent shape and size. PC3 was associated with overall flavour and aroma, with Enrosadira (Arilje) scoring high for sweet aroma and juiciness, while the commercial sample Premia displayed lower scores, indicating a less desirable flavour profile.

These results highlight the high quality and distinct sensory characteristics of frozen Arilje raspberries, particularly in terms of flavour, texture, and aroma, which set them apart from other regional and commercial varieties. The findings contribute valuable insights to producers, distributors, and stakeholders in the raspberry industry, helping to improve product quality, better align with consumer preferences, and reinforce the distinctiveness and perspective of frozen Arilje raspberries in the market.

***Key words**: frozen raspberries, sensory lexicon, rate-all-that-apply (RATA) methodology*

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SENSORY CHARACTERIZATION OF FRESH ARILJE RASPBERRIES USING RAPID EVALUATION TECHNIQUES

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The objective was to define the sensory attributes of fresh Arilje raspberries produced within the protected designation of origin (PDO) region using rapid evaluation techniques. A total of six raspberry varieties from different locations and altitudes were evaluated, including Vilamet, Fertodi, Tulamin, Enrosadira, Sky, and Miker, with Vilamet and Tulamin replicated to ensure panel consistency. A panel of 15 assessors from the *Arilje Raspberry Association* utilized the Rate-All-That-Apply (RATA) methodology, assessing 47 sensory descriptors grouped into appearance, odour, taste, flavour, texture, aftertaste, and trigeminal effects.
The sensory evaluation was conducted using a 5-point scale, and data were analyzed with a two-way ANOVA model and Tukey's post hoc test. Significant differences ($p < 0.05$) were observed in several sensory attributes, particularly for flavour and taste, with Vilamet and Fertodi scoring the highest. Fruit size and colour were also found to be significant, especially for Vilamet and Enrosadira. Principal Component Analysis (PCA) revealed three key factors influencing sensory profiles: freshness and shape, colour, and flavour. Vilamet and Fertodi were strongly correlated with freshness and shape, while Tulamin and Enrosadira displayed distinct characteristics.
The study also identified higher consistency in evaluating Vilamet compared to Tulamin and Enrosadira, suggesting that Vilamet and Fertodi exhibit more stable sensory qualities. These results highlight the unique attributes of fresh Arilje raspberries, including their intense red colour, medium to large size, uniform shape, rich fruity aroma with possible floral hints, and well-balanced flavour with a mix of sweetness and mild acidity. The raspberries' juicy texture and long-lasting pleasant aftertaste further distinguish them as a high-quality PDO product.
This research provides valuable insights into the sensory characteristics of fresh Arilje raspberries and demonstrates the effectiveness of rapid evaluation techniques, such as RATA, in profiling the sensory attributes of fruitproducts. The findings support the initiative for PDO protection of Arilje raspberries' based on their unique sensory qualities, offering guidance for producers to enhance product quality and standardization. These sensory attributes reflect the exceptional growing conditions in Arilje and support PDO protection strategies.
***Key words**: fresh raspberries, sensory characterization, rate-all-that-apply (RATA) methodology*

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In line with the United Nations' universal strategy (Agenda 2030) and contributions to the sustainable development goal (Goal 12: Ensure sustainable consumption and production patterns).

NUTRITIONAL PROFILE OF SOME EDIBLE FRESHWATER AND MARINE FISH SPECIES. A REVIEW

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Fish constitutes a critical dietary component, providing high-quality protein, essential fatty acids, vitamins, and minerals, thereby serving as an indispensable element of a nutritionally balanced human diet. This review undertakes a comparative evaluation of the nutritional profiles of selected edible freshwater and marine fish species, elucidating their divergent and convergent attributes in macronutrients, micronutrients and bioactive compounds. A pressing challenge, however, lies in the dietary reliance of nutritionally vulnerable populations on diverse aquatic species for which nutrient composition data remain fragmented, inconsistently cataloged, or entirely unavailable. Such gaps hinder targeted dietary interventions and public health strategies. To address this limitation, our analysis synthesizes extant literature on the nutritional composition of globally prevalent freshwater and marine species, prioritizing those most frequently consumed across socioeconomic and geographic contexts. Freshwater and marine fish each confer distinct nutritional advantages, rendering them complementary pillars of a health-optimized diet. Marine species, such as salmon, mackerel, and sardines, are distinguished by their elevated concentrations of long-chain omega-3 polyunsaturated fatty acids (eicosatetraenoic acid [EPA] and docosahexaenoic acid [DHA]), at the same time being a primary dietary source of vitamin D. Freshwater species provide high-quality proteins with complete amino acid profiles, alongside B-complex vitamins (notably B12) and minerals such as iodine, selenium, zinc, and calcium. Both types exhibit comparable protein content (15–25% of edible mass), with amino acid profiles meeting human physiological requirements. Lipids of marine species are enriched with EPA and DHA, whereas freshwater fish lipids may exhibit higher proportions of omega-6 fatty acids. Marine fish often contain higher selenium and zinc, while small freshwater species have a significant calcium bioavailability. The literature reviewed shows that integrating both freshwater and marine fish into dietary frameworks can mitigate nutrient deficiencies and support holistic health.
***Key words**: freshwater fish, marine fish, nutritional profile, health benefits of fish*

THE LINK BETWEEN THE STRUCTURAL ADJUSTMENTS AND THE CROP RANGE IN ROMANIAN WESTERN AGRICULTURE

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The obvious changes in Romanian agriculture after thirty-five years are demanding an analysis capable of discerning the factors and the mainstream choice of the farmers throughout a period of shifts and changes with severe adjustments. The research aims to extract and interpret the findings of a medium-term analysis starting with the change of the political regime back in 1990 and ending with the present period as the midterm of the third EU programming period. The often changes in the public policy with regard to agriculture and rural development of the first analysed decade overlaps with the process of land restitution; here the choices are often strictly opportunity based, inertial or accidental. The period suffered severely from lack of information and communication on one side and from the collapse of the processing industries, a fragmented market and huge fluctuation in price, high inflation rates and unstable exchange rates. The second decade benefits from a more structured and strategically oriented targets as the EU pre-accession process produced as main yet also side effects for specific crops, including the industrial crops. The third decade, or the past fifteen years, are drawing a relatively clear orientation with crops dropped out completely, others reduced to a hobby size while the main and few market crops are dominating the landscape and the economy. Although the structural changes have played a central role, in certain cases completely eliminating players, farms and crops from the market, the other factors among which the industry remain essential. The agriculture in the western part of Romania, in the Region V West and more specifically in the County of Timis, ranked first as importance and contribution of agriculture not only in the region yet at national level, no longer resemble to anything that used to be. The current differences have completely changed the agricultural and rural landscape of the county, primarily as result of the structural early changes and adaptation. The market and the industry complete the table of the change factors while the anthropic factors have improved both in structure as distribution by age and perspective, addressing the agricultural practice and farming as a business model. Along the changes and shifts during the past three decades the most noticeable looser is the family-farming as economic pressure, sudden and often shocks of all kind (public health, geopolitics, energy, markets) have weakened and eliminated an important number of resilient players.
Key words: *structural changes in agriculture, EU accession, market pressure*

BENEFICIAL IMPACTS OF CHOKEBERRY AND TART CHERRY BASED DIETARY SUPPLEMENTS IN DIABETICS

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Diabetes mellitus (DM) is a metabolic disorder that may cause increased risk of various diseases mostly cardiovascular ones. Currently, available therapies are effective for some individuals, but not all. As a result, there is a high need for novel antidiabetic medications or treatments which can help to regulate glycemia or reduce the negative consequences of diabetes, especially on blood vessels. Epidemiological studies have shown that diet can significantly affect blood sugar levels, and berries rich in polyphenols, especially anthocyanins, have shown particularly good effects. Concerning the chemical composition of chokeberry (*Aronia melanocarpa*), it has been highlighted that anthocyanins are the most important pharmacologically active compounds responsible for its antioxidative, anti-inflammatory, and vasoprotective effects. More recently, the promising potential of cherry juice, originated from tart cherry (*Prunus cerasus*), a low-calorie fruit rich in secondary metabolites such as anthocyanins, hydoxycinnamates, and flavan-3-ols, in terms of its antioxidant (stimulation of superoxide dismutase and glutathione peroxidase) and anti-inflammatory properties (inhibition of cyclooxygenase-2) was revealed Our aim was to evaluate the effect of combined oral consumption of two dietary supplements based on chokeberry and tart cherry juices over a period of 90 days on HbA1C and, systolic and diastolic pressure, intimo-medial complex (IMC) where atherosclerosis takes place and safety in 27 volunteers with diabetes type 2. Moreover, *in vitro* antidiabetic activity of juices and supplements were studied. Statistically significant decrease in the thickness of both, carotid and femoral artery was noticed. Slight decrease in systolic and diastolic pressure was observed but it was not statistically significant while an improvement in HbA1C was observed in 62% of respondents. Moreover, the levels of creatinine, urea, ALT and AST values remained within normal limits, which indicates that the products did not have negative effects on the liver and kidneys during the study pointed its safety. *In vitro* inhibition of both, alpha-glucosidase and alpha-amylase was noticed for chokeberry and tart cherry juices as well as for both dietary supplements (IC_{50} 0.11 ± 0.02, 21.77 ± 1.66, 0.06 ± 0.01, 0.08 ± 0.01, 5.13 ± 0.11, 12.51 ± 0.83, 6.89 ± 0.36, 9.28 ± 0.04 mg/mL, respectively).
Key words*: chokeberry, tart cherry, dietary supplements, diabetes*

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POVOLJNI EFEKTI KONZUMACIJE DODATAKA ISHRANI NA BAZI SOKOVA ARONIJE I VIŠNJE KOD DIJABETIČARA

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Dijabetes melitus (DM) je metabolički poremećaj koji može uzrokovati povećan rizik od raznih bolesti, uglavnom kardiovaskularnih. Trenutno, dostupne terapije su efikasne za neke pojedince, ali ne za sve. Kao rezultat toga, postoji velika potreba za novim antidijabetičkim lekovima ili tretmanima koji mogu pomoći da se reguliše glikemija ili smanje negativne posledice dijabetesa, posebno na krvne sudove. Epidemiološke studije su pokazale da ishrana može značajno da utiče na nivo šećera u krvi I zdravlje krvnih sudova, a posebno dobro dejstvo pokazuje bobičasto voće bogato polifenolima, posebno antocijanima. Što se tiče hemijskog sastava aronije (*Aronia melanocarpa*), poznato je da su antocijanini najvažnija farmakološki aktivna jedinjenja odgovorna za njeno antioksidativno, antiinflamatorno i vazoprotektivno dejstvo. U skorije vreme, uočen je obećavajući potencijal soka od višnje (*Prunus cerasus*), niskokalorične voćke bogate sekundarnim metabolitima kao što su antocijani, hidroksicinamati i flavan-3-oli, u smislu njegovog antioksidantnog (stimulacija superoksida dismutaza i glutation peroksidaza) i antiinflamatornog svojstva (inhibicija ciklooksigenaze-2). Cilj našeg istraživanja je bio da procenimo efekat kombinovane oralne konzumacije dva dijetetska suplementa na bazi sokova od aronije i višnje u periodu od 90 dana na HbA1C, sistolni i dijastolni pritisak, debljinu intimo-medijalnog kompleksa (IMK) gde se odvija ateroskleroza i bezbednost kod 27 dobrovoljaca sa dijabetesom tipa 2. Ispitana je i *in vitro* antidijabetična aktivnost sokova i suplemenata. Uočeno je statistički značajno smanjenje debljine i karotidne i femoralne arterije. Uočeno je blago smanjenje sistolnog i dijastolnog pritiska, ali nije bilo statistički značajno, dok je poboljšanje u novou HbA1C primećeno kod 62% ispitanika. Nivoi kreatinina, uree, ALT i AST su ostali u granicama normale, što ukazuje da proizvodi nisu imali negativan uticaj na jetru i bubrege tokom ispitivanja, što ukazuje na njihovu bezbednost. *In vitro* inhibicija alfa-glukozidaze i alfa-amilaze je pokazana za sokove od aronije i višnje, kao i za oba dijetetska suplementa (IC_{50} 0,11 ± 0,02, 21,77 ± 1,66, 0,06 ± 0,01 ± 0,01 ± 0,11, 12,51 ± 0,83, 6,89 ± 0,36, 9,28 ± 0,04 mg/mL, respektivno).
***Ključne reči**: aronija, višnja, dodaci ishrani, dijabetes*

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NOVEL APPROACHES TO UTILIZING OF PRUNING RESIDUES OF RASPBERRIES AND BLACKBERRIES

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Raspberries and blackberries are fruits grown in relatively large areas in Serbia. In the fall, these plants are pruned and it is necessary to remove the pruning residues from the orchard to reduce the possibility of infection. One of the possibilities for their use that comes to mind first is the use for obtaining energy. These residues can be burned directly or used to produce briquettes or pellets. The problem with these residues is that they are not generated in large amounts on an annual basis compared to other post-harvest residues or forestry residues. Another problem is that these fruit species are mostly grown in mountain areas and mostly in small plantations, so their collection is energy-demanding. However, the pruning residues that are collected could be mixed in a certain ratio with some other lignocellulosic raw material in the process of briquette or pellet production.
This work aimed to examine the possibility of an improved way of using raspberry and blackberry cane as biosorbents of heavy metal ions from water. Our earlier research included some other post-harvest residues and sawdust of different types of wood. The canes must first be chopped and milled, like other lignocellulosic materials. For the experiments to be reproducible, the ground material is sieved through a set of sieves. The 224-400 μm fraction was used in the adsorption experiments. Hexavalent chromium, which often occurs in wastewater, was chosen to represent heavy metals for the tests. Biosorption was carried out in model water with different initial concentrations of chromium(VI) ions, at pH 2. First of all, the required contact time of biosorbent and water was examined. For the raspberry stalk, it was determined that the contact time needed to establish the adsorption equilibrium is 60 min, while for the blackberry stalk, it is 30 minutes. Adsorption from model water with different initial concentrations of chromium(VI) ions enables to determine the maximum adsorption capacity under the specified experimental conditions. It was 37 mg/g for the raspberry cane, and 10.2 mg/g for the blackberry cane. The blackberry cane has a significantly lower adsorption capacity than the raspberry cane, and in addition, it leaches significantly more organic matter into the water during adsorption, which is undesirable. Many lignocellulosic substrates leach organic matter into water during adsorption. After adsorption by raspberry and blackberry stems, COD in water was 169 mgO_2/l and 563 mgO_2/l, respectively. In the case of other lignocellulosic materials that we examined earlier, COD in water after adsorption ranged from 31 mgO_2/l for poplar wood sawdust to 447 mgO_2/l for black locust wood sawdust. Based on the obtained results, it can be concluded that the raspberry cane can be successfully used as an adsorbent of chromium(VI) ions from aqueous solutions, and further tests with this biosorbent can be continued.
Key words*: raspberry cane, blackberry cane, biosorption, chromium*

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NOVE MOGUĆNOSTI PRIMENE REZIDBENIH OSTATAKA MALINE I KUPINE

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Malina i kupina su voće koje se u Srbiji gaji na relativno velikim površinama. U jesen se ove biljke orezuju i potrebno je da se rezidbeni ostaci iznesu iz voćnjaka da bi se smanjila mogućnost pojave zaraze. Jedna od mogućnosti za njihovo iskorišćenje je ono što i prvo pada na pamet, a to je upotreba za dobijanje energije. Ovi ostaci se mogu spaljivati direktno ili koristiti za proizvodnju briketa ili peleta. Problem kod ovih ostataka je što ih nema mnogo na godišnjem nivou, upoređujući sa dugim posležetvenim ostacima ili ostacima u šumarstvu. Drugi problem je što se ove voćne vrste više gaje u planinskim predelima i većinom u malim zasadima, te je njihovo prikupljanje energetski zahtevno. Ipak, rezidbeni ostaci koji se sakupe mogli bi se mešati u određenom odnosu sa nekom drugom lignocelulozom sirovinom u procesu proizvodnje briketa ili peleta.
Zadatak ovog rada je bio da se ispita mogućnost unapređenog načina iskorišćenja stabljika maline i kupine kao biosorbenta jona teških metala iz vode. Našim ranijim istraživanjima su bili obuhvaćeni neki drugi posležetveni ostaci i piljevina različitih vrsti drveta. Stabljike je prvo potrebno, kao i druge lignocelulozne materijale, usitniti. Da bi ogledi bili ponovljivi usitnjeni materijal se proseje kroz set sita. Frakcija od 224-400 μm se koristila u ogledima adsorpcije. Kao predstavnik teških metala za oglede je odabran šestovalentni hrom koji se često javlja u otpadnim vodama. Biosorpcija je rađena u model vodi sa različitom početnom koncentracijom jona hroma(VI), na pH 2. Prvo je ispitano potrebno vreme kontakta biosorbenta i vode. Za stabljiku maline je utvrđeno da je vreme kontakta potrebno za uspostavljanje adsorpcione ravnoteže 60 minuta, dok je za stabljiku kupine to 30 minuta. Adsorpcijom iz model vode sa različitom početnom koncentracijom jona hroma(VI) se mogao utvrditi maksimalni kapacitet adsorpcije u navedenim eksperimentalnim uslovima. Za stabljiku maline je iznosio 37 mg/g, a za stabljiku kupine 10,2 mg/g. Stabljika kupine ima znatno manji adsorpcioni kapacitet od stabljike maline, a pored toga izlužuje znatno više organskih materija u vodu tokom adsorpcije, što je nepoželjno. Mnogi lignocelulozni supstrati izlužuju organsku materiju u vodu tokom adsorpcije. Nakon adsorpcije stabljikom maline i kupine, HPK u vodi je bio 169 mgO_2/l i 563 mgO_2/l, sledstveno. Kod drugih lignoceluloznih materijala koje smo ranije ispitivali, HPK u vodi nakon adsorpcije se kretao od 31 mgO_2/l za piljevinu drveta topole, do 447 mgO_2/l za piljevinu drveta bagrema. Na osnovu dobijenih rezultata se može zaključiti da se stabljika maline može uspešno koristiti kao adsorbent jona hroma(VI) iz vodenih rastvora, te da se ispitivanja sa ovim biosorbentom mogu dalje nastaviti.
***Ključne reči**: stabljika maline, stabljika kupine, biosorpcija, hrom*

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INNOVATIVE NON-THERMAL TECHNOLOGY TO IMPROVE SAFETY AND QUALITY IN READY-TO-EAT VEGETABLES

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Chemical sanitizers are widely used for ready-to-eat vegetables (REVs) decontaminating in the food industry but can compromise quality, pose environmental and health risks. Cold plasma has emerged as a promising non-thermal alternative, generating reactive species (ROS and RNS) that effectively reduce microbial loads, while preserving nutritional and sensory qualities. This study evaluated the efficacy of cold plasma processes, specifically Plasma-Activated Water (PAW), as decontamination method for REVs, e.g. baby leaf lettuce and shredded carrots, at various treatment times in comparison with a conventional sanitizer (sodium hypochlorite). In baby leaf lettuce, PAW significantly reduced coliforms, total mesophilic and psychrotrophic bacteria and *Pseudomonas* spp., especially after 10 minutes of washing; reductions in spoilage *Pseudomonas* spp. and coliform populations were over 2 log CFU/g. Gas chromatography-mass spectrometry (GC/MS) analysis also revealed that PAW-treated lettuce presented higher levels of green aroma compounds (3,3,5-trimethylcyclohexyl acetate and cis-2-pentenol) and lower levels of aldehydes (hexanal, methyl butanal) than chlorine-washed samples, thus suggesting improved sensory attributes. Follow-up experiments tested PAW's decontamination effect on shredded carrots deliberately contaminated with two strains of *Escherichia coli*, *Salmonella* Enteritidis, or *Listeria monocytogenes*. The results indicated 2-Log reductions for *Escherichia coli* and *Salmonella* Enteritidis (both strains), while *Listeria monocytogenes* was more resistant. PAW treatment likewise reduced the total spoilage microbial load on uninoculated carrots, including Enterobacteriaceae, mesophilic and psychrotrophic bacteria, *Pseudomonas* spp., lactobacilli, yeasts, and lactococci. Throughout the storage, the microbial load of total coliforms, lactobacilli and *Pseudomonas* spp. were below the 10^7 CFU/g threshold after 5 days. Physicochemical analyses showed that PAW slightly decreased pH with increasing treatment time and did not induce significant changes in lightness parameters throughout the storage period. Overall, PAW can potentially be an effective decontamination method in both matrices tested and improved sensory quality, providing a sustainable alternative to conventional chemical treatments.

***Key words**: Non-thermal technology, plasma activated water, decontamination, ready-to-eat vegetables, quality, safety*

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THE INFLUENCE OF GENOTYPE AND SOWING DENSITY ON AGRONOMIC CHARACTERISTICS OF CORN HYBRIDS FOR SILAGE PRODUCTION

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In the overall structure of corn production in the Republic of Croatia, corn production for silage production amounts to about 70,000 ha. The plant mass produced is used for fodder purposes in livestock farming, but also for energy production in biogas plants. The conditions of the growing year, especially the distribution and amount of precipitation as well as the temperature maxima and relative humidity during the vegetation period, influence the yield and the agronomic characteristics of corn hybrids. The literature shows that the drought tolerance of certain corn hybrids is very high and that the influence of the genotype is of great importance for the stability and quality of corn production for grain or silage. With the right choice of corn genotype/hybrid and optimal sowing under less favourable/unfavourable climatic conditions, we can achieve good and high-quality yields of corn grains and plant mass.

The research was conducted over three years (2022, 2023 and 2024) in the counties of Vukovar-Srijem, Osijek-Baranya and Brod-Posavina in field trials at five locations (Bobota, Bodovaljci, Vrpolje, Budrovci, Zapolje) with five corn hybrids (Lila, Rudolfov, Velimir, Tomasov, Drava 404). Agrotechnics and fertilization were standard at all locations. Sowing took place in the first and second decade of April, ensiling in August. The sowing pattern was 65,000, 70,000 and 75,000 plants/ha, and the target fertilization was 180 kg/ha of nitrogen, 120 kg/ha of phosphorus and 150 kg/ha of potassium. During the research, there were three significantly different production years. The year 2022 was characterized by average precipitation and temperatures during the vegetation period, the year 2023 by significantly above-average precipitation and the year 2024 by extreme drought with extremely high and long-lasting temperatures combined with low relative humidity. Depending on the climatic conditions, the silage yield fluctuated between 37 t/ha and 83 t/ha and the grain yield between 7.31 t/ha and 16.47 t/ha. According to the research results, the lowest yield fluctuations were recorded with the sowing pattern of 65,000 plants/ha at the Bodovaljci and the most stable hybrid was Rudolfov 60.

***Key words**: corn, silage, climatic conditions, production*

Acknowledgment of funding: The research results were obtained as part of the project's implementation: "Innovative technological and technical solutions on dairy farms in the Brod-Posavina County for the purpose of greater productivity and profitability of family farms".

UTJECAJ GENOTIPA I GUSTOĆE SJETVE NA GOSPODARSKA SVOJSTVA HIBRIDA KUKURUZA ZA PROIZVODNJU SILAŽE

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U ukupnoj strukturi proizvodnje kukuruza u Republici Hrvatskoj, proizvodnja kukuruza namjenjena za proizvodnju silažu je oko 70.000 ha. Proizvedena biljna masa se koristi za potrebe ishrane u stočarskoj proizvodnji ali i za proizvodnju energije u bioplinskim postrojenjima. Uvjeti proizvodne godine, prvenstveno raspored i količina oborina uz temperaturne maksimume i relativnu vlagu zraka tijekom vegetacije utječu na visinu prinosa i odlike gospodarskih svojstava hibrida kukuruza. Literaturni podaci pokazuju da je tolerantnost pojedinih hibrida kukuruza na sušu vrlo značajna i da je za stabilnost te kvalitetu proizvodnje kukuruza za zrno ili silažu vrlo značajan utjecaj genotipa. Pravilni izborom genotipa/hibrida kukuruza i optimalnom sjetvom u manje povoljnim/nepovoljnim klimatskim uvjetima možemo ostvariti dobre i kvalitetne prinose zrna i biljne mase kukuruza.

Istraživanje je provođeno tijekom godine (2022., 2023. i 2024.) na području Vukovarsko-srijemske, Osječko-baranjske i Brodsko-posavske županije u poljskim pokusima na pet lokaliteta (Bobota, Bodovaljci, Vrpolje, Budrovci, Zapolje) s pet različitih hibrida kukuruza (Lila, Rudolfov, Velimir, Tomasov, Drava 404). Agrotehnika i gnojidba na svim lokalitetima bila je uobičajena. Sjetva u prvoj drugoj dekadi travnja a siliranje u kolovozu. Sjetveni sklop je na 65000, 70000 i 75000 biljaka / ha, a ciljana gnojidba 180kg/ha dušika, 120 kg/ha fosfora i 150kg/ha kalija. Tijekom istraživanja bile su tri značajno različite proizvodne godine; 2022. godina tijkom vegetacije bila je sa prosječnim vrijednostima oborina i temperatura, 2023. izrazito većim količinama oborina od prosjeka i 2024. izrazito sušna i sa ekstremno visokim te dugotrajnim temperaturama praćenim malom relativnom vlagom. Ovisno o klimatskim uvjetima prinos silaže bio je od 37t/ha do 83t/ha, prinos zrna od 7,31t/ha do 16,47t/ha. Prema rezultatima istraživanja najmanje variranja prinosa bilo je pri sklopu 65000 biljaka/ha, na lokaliteu Bodovaljci, a najstabilniji hibrid bio je Rudolfov 60.

Ključne riječi: *kukuruz, silaža, klimatski uvjeti, proizvodnja*

Zahvalnica: Rezultati istraživanja proizašli su iz provedbe projekta: “Inovativna tehnološka-tehnička rješenja na mliječnim farmama Brodsko-posavske Zupanije u cilju veće proizvodnosti i rentabilnosti OPG-a”.

OPTIMIZATION OF PUMPING STATIONS IN VOJVODINA THROUGH ENERGY CONSUMPTION ANALYSIS AND IMPROVEMENT OPPORTUNITIES

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Agriculture, particularly crop production, is the backbone of Vojvodina's economic development, covering more than 70% of Serbia's arable land. With fertile soils and well-developed infrastructure, Vojvodina is the Serbian primary agricultural region, dominated by wheat, corn, soybean, and sugar beet cultivation. However, historically, around 75% of this area was covered by wetlands and subject to seasonal flooding, posing significant challenges to agricultural production. Large-scale land reclamation efforts, including river regulation and the construction of drainage systems, have significantly improved conditions for crop cultivation.

Efficient drainage is essential for sustainable agriculture in regions with seasonal excess precipitation and shallow groundwater tables. Pumping stations serve as critical hydraulic structures for controlled water evacuation, but their inefficiency can lead to excessive energy consumption and increased operational costs. This study aims to analyze the operational regime and energy consumption of the Itebej-Crnja pumping station to identify optimization opportunities and reduce energy costs.

The study was conducted on the Itebej-Crnja drainage system, covering an area of 27,309.42 ha, with excess water discharged into the Stari Begej recipient. Data on pump operating hours, precipitation levels, water table fluctuations, and groundwater levels were analyzed for the period 2003–2023. Energy consumption analysis was based on pump unit power and operational hours during a period of five years, from 2019 to 2023. Statistical data analysis enabled the identification of key factors influencing variations in the pumping station's operational regime.

The analysis revealed that rainfall distribution, groundwater dynamics, and the hydraulic capacity of the drainage system are the primary factors affecting pumping station performance. Seasonal fluctuations in energy consumption were identified, with the highest operational costs recorded during extreme hydrological years. Optimization of the pumping station's operation through improved planning and exploitation strategies could reduce energy costs by 10–15%, significantly contributing to the economic sustainability of the drainage system.

This research provides a foundation for improving the operational strategies of pumping stations, enhancing drainage efficiency in agricultural regions. Future studies could focus on the implementation of automated management systems to achieve greater energy efficiency and reduce operational costs.

***Key words**: Pumping stations, drainage system, energy consumption*

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BLUE CARBON IN FRESHWATER ECOSYSTEMS OF VOJVODINA, SERBIA: POTENTIALS AND CHALLENGES

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The Pannonian Plain, the largest lowland region in the Central Europe, encompasses a diverse freshwater ecosystems, including river valleys, wetlands, lakes, and canal networks. Historically, Vojvodina, located in the northern part of Serbia and forming the southernmost section of the Pannonian Plain, was characterized by extensive wetland areas that functioned as natural carbon sinks. However, extensive hydrotechnical modifications and long-term alterations in hydrological regimes over the past two centuries have significantly influenced carbon sequestration dynamics and emission patterns. While coastal ecosystems are widely recognized as key blue carbon sinks, the capacity of inland freshwater ecosystems for carbon storage and their broader role in climate regulation remain insufficiently investigated.

Vojvodina features hydromorphologically diverse ecosystems, including river deltas, seasonally flooded areas, natural retensions and artificial reservoirs. Their role in carbon remains insufficiently understood due to seasonal water level fluctuations, the presence of organic sediments, and anthropogenic influences. This study aims to assess the capacity of freshwater ecosystems in the Vojvodina for blue carbon storage, identify key factors influencing carbon balance, and explore strategies to enhance their role in climate policy frameworks.

The study analyzes carbon fluxes across various types of freshwater ecosystems, including wetlands (e.g., Obedska Bara, Carska Bara), river deltas, and natural retention areas (e.g., Zasavica, Jegrička) and artificial reservoirs. Data sources include field measurements (sediment sampling, greenhouse gas flux analysis), satellite monitoring of vegetation and hydrological changes, and carbon cycle modeling. Special emphasis is placed on anthropogenic influences such as river regulation, eutrophication, and land-use changes.

Preliminary findings indicate that wetlands and seasonally flooded floodplains have significant potential for carbon sequestration, whereas regulated waterways and artificial aquatic systems often act as net sources of greenhouse gases, particularly methane (CH_4). Changes in hydrological regimes due to hydrotechnical modifications and climate variability directly affect the efficiency of carbon storage in sediments. Optimizing water management strategies and restoring natural wetland functions could improve carbon sequestration potential of these ecosystems while mitigating greenhouse gas emissions.

The findings of this study contribute to the development of conservation and restoration policies for freshwater ecosystems in Vojvodina in the context of climate change. Integrating these ecosystems into blue carbon management frameworks could improve carbon sequestration strategies and mitigate emissions from continental water bodies.

***Key words**: Blue carbon, freshwater, ecosystem, Vojvodina*

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INNOVATIVE THREE-DIMENSIONAL 3D-ESSERTS WITH DIETARY SUPPLEMENTS IN EDIBLE PACKAGING

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3D food printing is an emerging processing technology poised to have a significant impact on the entire food industry and consumer health. It enables transformation of high-quality food ingredients into special designed, highly customized 3D printed foods, such as "3D-esserts" with edible packaging. One notable application of this technology is the creation of fully edible packaging made from ingredients that are safe for human or pet consumption. Familiarizing consumers with these innovations and demonstrating their relevance to both the human and pet food industry is crucial. A key example of edible and printable material includes desserts with supplemental nutrients tailored to an individual's dietary needs.

Unlike conventional food, dietary supplements are intended to enhance nutrition by incorporating essential proteins, vitamins, minerals, bioactive compounds, live beneficial microbes, or other beneficial nutrients like methylsulfonylmethane. These advancements in 3D food printing are driving the rise of personalized nutrition. Moreover, 3D printing allows for the personalization of both food and packaging, adapting to individual preferences and dietary requirements. From a societal perspective, public opinion generally supports the development of new food technologies - especially 3D food printing – due to its innovative and visually appealing products. Edible films and coatings have gained significant attention in recent years due to their advantages over synthetic polymer films. Unlike traditional packaging materials, edible films can be consumed along with the packaged product. In addition to serving as effective vapor and gas barriers, they enhance food quality, extend shelf life, and reduce packaging waste. They can also serve as carriers of bioactive compounds, further enhancing the functional properties of food. The combination of "3D-esserts" and 3D-printed edible packaging represents a promising approach to environmental sustainability. By replacing plastic packaging with edible alternatives, 3D food printing can help reduce plastic waste and promote a circular economy.

As part of the HRID project, recipes compatible with 3D food printing technology will be developed and presented to meet specific nutritional and health requirements.

***Key words**: dietary supplements, edible packaging, 3D-esserts, 3D food, 3D printing*

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INOVATIVNI TRODIMENZIONALNI 3D-ESERTI S DODACIMA PREHRANI U JESTIVOM PAKIRANJU

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3D ispis hrane nova je tehnologija obrade koja će imati značajan utjecaj na cjelokupnu prehrambenu industriju i zdravlje potrošača. Omogućuje transformaciju visokokvalitetnih sastojaka hrane u posebno dizajniranu, visoko prilagođenu 3D ispisanu hranu, kao što su „3D-eserti“s jestivim pakiranjem. Jedna značajna primjena ove tehnologije je stvaranje potpuno jestivih pakiranja napravljenih od sastojaka koji su sigurni za prehranu ljudi ili kućnih ljubimaca. Upoznavanje potrošača s ovim inovacijama i spominjanje njihove važnosti za prehrambenu industriju i industriju hrane za kućne ljubimce od ključne je važnosti. Ključni primjer jestivog materijala koji se može ispisati uključuje deserte s dodatnim hranjivim tvarima prilagođene prehrambenim potrebama pojedinca. Za razliku od konvencionalne hrane, dodaci prehrani namijenjeni su poboljšanju prehrane uključivanjem esencijalnih proteina, vitamina, minerala, bioaktivnih spojeva, korisnih živih mikroba ili drugih korisnih hranjivih tvari poput metilsulfonilmetana. Ovaj napredak u 3D ispisu hrane pokreće uspon personalizirane prehrane.

Štoviše, 3D ispis omogućuje personalizaciju hrane i pakiranja, prilagođavajući se individualnim preferencijama i prehrambenim zahtjevima. Iz društvene perspektive, javno mnijenje općenito podržava razvoj novih prehrambenih tehnologija - posebno 3D printanje hrane zbog svojih inovativnih i vizualno privlačnih proizvoda. Jestivi filmovi i premazi privukli su značajnu pozornost posljednjih godina zbog svojih prednosti u odnosu na filmove od sintetičkih polimera. Za razliku od tradicionalnih materijala za pakiranje, jestive folije mogu se konzumirati zajedno s pakiranim proizvodom. Osim što služe kao učinkovite parne i plinske barijere, poboljšavaju kvalitetu hrane, produljuju rok trajanja i smanjuju otpadnu ambalažu. Oni također mogu poslužiti kao nosioci bioaktivnih spojeva, dodatno poboljšavajući funkcionalna svojstva hrane. Kombinacija “3D-eserata” i 3D ispisane jestive ambalaže predstavlja obećavajući pristup održivosti okoliša. Zamjenom plastične ambalaže jestivim alternativama, 3D ispis hrane može pomoći u smanjenju plastičnog otpada i promovirati kružno gospodarstvo.

U sklopu projekta HRID razvit će se i prezentovati recepti kompatibilni s tehnologijom 3D printanja hrane kako bi se zadovoljili specifični prehrambeni i zdravstveni zahtjevi.

Ključne riječi: *dodaci prehrani, jestiva ambalaža, 3D hrana, 3D ispis, 3D-eserti*

Zahvala za financiranje: Ovaj rad poduprlo je Veleučilište u Karlovcu kroz interni projekt: Hranjivi Inovativni trodimenzijski 3D-eserti (HRID).

FERMENTATION OF POPLAR BUD EXTRACTS USING LACTIC ACID BACTERIA

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Poplar bud extracts of various poplar species are implemented in traditional medicine for wound healing due to their astringent and antiseptic properties. In recent years, poplar trees have been cultivated for the purpose of wood biomass production, whereas side shoots and buds are discarded and used as fuel. On the other hand, lactic acid bacteria (LAB) are widely used in producing fermented and functional food products, for their probiotic properties and ability to produce enzymes, acids, and other bioactive compounds. The aim of this study was to examine the chemical composition of prepared poplar bud extracts before lactic acid fermentation, as well as the effect the extracts had on the viability of LAB cells. Due to abundance and high availability, buds of cultivated poplar species *Populus x euramericana* (Dode) Guinier I-214 were utilized in this research.

Maceration and ultrasonic extraction were the selected methods for extracting poplar buds, while 50% (v/v) ethanol was used as a solvent. The obtained liquid extracts were evaporated using a rotary vacuum evaporator. The chemical composition of poplar bud extracts was examined by high-performance liquid chromatography (HPLC), while their antimicrobial activity was assessed using the agar well diffusion method. Fermentation of prepared extracts was carried out using *Lacticaseibacillus rhamnosus* ATCC 7469, *Ligilactobacillus salivarius* ATCC11741, and *Lactiplantibacillus plantarum* 299v as model microorganisms. The potential antimicrobial activity of extracts was assessed against *Escherichia coli, Bacillus cereus, Staphylococcus aureus* and *Candida albicans.* To analyze the effect of extract concentration on the fermentation process and cell viability, two different concentrations of extracts were prepared, by dissolving the extracts in 3% DMSO and sterile water. After 24 hours of fermentation, the number of viable LAB cells and the pH of the extracts were measured.

The results of the HPLC analysis demonstrated that the poplar bud extract obtained by ultrasonic extraction (UE) had an overall higher concentration of polyphenolic compounds than the macerate (M). Notably, UE mainly contained phenolic acids (caffeic and rosmaric acid), while M was predominantly comprised of flavonoids (pinocembrin, chrysin, and pinostrobin). The number of viable LAB cells after extract fermentation showed that prepared poplar bud extracts were not suitable for the cultivation and survival of examined bacterial species. Consequently, only a certain number of *L. plantarum* cells were viable after fermentation in the UE extract, which contained 8 mg/ml of dry extract. The agar well diffusion test revealed that the prepared extracts exhibited antimicrobial activity towards *Staphylococcus aureus* and *Bacillus cereus,* but did not show inhibitory effects against *Escherichia coli* and *Candida albicans.* Furthermore, the decrease in the pH value of the extracts after 24 hours of fermentation indicated biotransformations by the examined LAB species.

In conclusion, in order to better understand the transformations that occur during fermentation, it is important to analyze the chemical composition of the extracts after fermentation. Additionally, alternative extraction methods and solvents should be explored to obtain extracts with improved solubility.

Keywords: *poplar, extraction, polyphenols, microbial transformation, lactic acid bacteria*

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FERMENTACIJA EKSTRAKATA PUPOLJAKA TOPOLE BAKTERIJAMA MLEČNE KISELINE

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Ekstrakti pupoljaka različitih vrsta topole se u tradicionalnoj medicini koriste za zarastanje rana, zbog svog adstrigentnog i antiseptičnog delovanja. Topole se danas gaje u cilju proizvodnje drvne biomase, a mladi bočni izdanci sa pupoljcima se odsecaju i najčešće koriste za ogrev. Sa druge strane, bakterije mlečne kiseline (BMK) imaju široku primenu u proizvodnji funkcionalne i fermentisane hrane, kao probiotici i proizvođači enzima, kiselina i drugih biološki aktivnih jedinjenja. Cilj ovog istraživanja bio je određivanje hemijskog sastava pripremljenih ekstrakata pupoljaka topole pre mlečno-kiselinske fermentacije, kao i ispitivanje uticaja ekstrakata na vijabilnost ćelija BMK. Kao biljna sirovina u ovom istraživanju, korišćeni su pupoljci gajene topole vrste *Populus x euramericana* (Dode) Guinier I-214.

Ekstrakti su pripremljeni maceracijom i ultrazvučnom ekstrakcijom, pri čemu je kao rastvarač korišćen 50% (v/v) etanol. Dobijeni tečni ekstrakti su upareni do suva pomoću rotacionog vakuum uparivača. Analiza hemijskog sastava izvršena je tečnom hromatografijom visokih performansi (HPLC), dok je antimikrobna aktivnost ispitana agar difuzionom metodom. Kao model mikroorganizmi za fermentaciju pripremljenih ekstrakata korišćeni su *Lacticaseibacillus rhamnozus* ATCC 7469, *Ligilactobacillus salivarius* ATCC11741 i *Lactiplantibacillus plantarum* 299v. Potencijalna antimikrobna aktivnost ekstrakata ispitivana je prema *Escherichia coli, Bacillus cereus, Staphylococcus aureus* i *Candida albicans.* U cilju analize uticaja koncentracije suvog ekstrakta na proces fermentacije i vijabilnost ćelija BMK, pripremljene su dve koncentracije ekstrakata, rastvaranjem odgovarajuće mase ekstrakta u 3% DMSO i sterilnoj vodi. Nakon 24 sata fermentacije, utvrđen je broj vijabilnih ćelija BMK i pH vrednost ekstrakata.

Rezultati HPLC analize pokazali su da ekstrakt dobijen ultrazvučnom ekstrakcijom (UZ) sadrži višu koncentraciju polifenolnih jedinjenja u poređenju sa maceratom (M). Ekstrakt UZ dominantno sadrži fenolne kiseline, pri čemu su najzastupljenije kofeinska i rozmarinska kiselina. Sa druge strane, uzorak M se pretežno sastoji od flavonoida, poput pinocembrina, hrizina i pinostrobina. Broj vijabilnih ćelija BMK ukazao je da pripremljeni ekstrakti pupoljaka topole nisu pogodni za rast posmatranih bakterijskih vrsta. Rast i preživljavanje pokazale su jedino bakterije vrste *L. plantarum,* u uzorku UZ koncentracije suvog ekstrakta 8 mg/ml. Agar difuzionim testom utvrđeno je da pripremljeni ekstrakti pokazuju antimikrobnu aktivnost prema *Staphylococcus aureus* i *Bacillus cereus,* ali nisu delovali inhibitorno na ćelije *Escherichia coli* i *Candida albicans.* Smanjenje pH vrednosti ekstrakata nakon 24 sata fermentacije može biti pokazatelj biotransformacija koje su nastale usled dejstva BMK.

U cilju boljeg razumevanja biotransformacija koje su se odvile u ekstraktima, neophodno je izvršiti hemijsku karakterizaciju ekstrakata nakon fermentacije. U daljem radu bi trebalo ispitati mogućnost implenetacije alternativnih metoda ekstrakcije ili primene drugačijeg rastvarača, kako bi se dobili ekstrakti pogodnijih karakteristika, prevashodno u pogledu rastvorljivosti.

Ključne reči: *topola, ekstrakcija, polifenoli, mikrobne transformacije, bakterije mlečne kiseline*

Zahvalnica: Autori se zahvaljuju Alijansi internacionalnih naučnih organizacija (Projekat: SparkGREEN, ANSO-CR-PP 2022-08) i Ministarstvu nauke, tehnološkog razvoja i inovacija Republike Srbije (Broj ugovora: 451-03-66/2024-03/200003, 451-03-65/2024-03/200135 i 451-03-66/2024-03/200287).

CHEMICAL CHARACTERIZATION OF CHOKEBERRY SEEDS AND THEIR DERIVED OIL: COMPOSITION AND POTENTIAL HEALTH BENEFITS

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Chokeberries are a rich source of bioactive compounds with potential health benefits for humans. The high concentrations of polyphenols, such as phenolic acids, flavonols, anthocyanins, flavanols, and proanthocyanidins, play a key role in their remarkable bioactivity. Chokeberry seeds, as well as oil obtained from them, can also be consumed as a food component, though it is less commonly found in typical diets. The aim of this research was to investigate the characteristics and nutrient composition of chokeberry seeds and the oil extracted from them. The oil was extracted using hexane as a solvent in a Soxhlet extractor for 6 hours at 60°C. Before analysis, fatty acids were converted into fatty acid methyl esters using a standard sulfuric acid procedure. Tocopherols and tocotrienols were analyzed using normal-phase HPLC with a fluorescence detector, while carotenoids were analyzed using normal-phase HPLC with a diode array detector. The seed oil demonstrated a high degree of unsaturation. Gas chromatography analysis revealed that the major unsaturated fatty acid was alpha-linolenic acid (80.0%), followed by oleic acid (10.4%). The main saturated fatty acid was palmitic acid (5.2%). Chokeberry seeds were also found to be rich in tocopherols, with α-tocopherol being the most prevalent (21.7 mg/100 g of seed), followed by β-tocopherol (3.3 mg/100 g). As for tocotrienols, only γ-tocotrienol was detected, with a content of 0.7 mg/100 g of seed. HPLC analysis also identified carotenoids, with (E)-β-carotene as the dominant compound (3.7 mg/100 g), followed by lutein (1.2 mg/100 g). The antioxidant capacity of chokeberry seeds was assessed using the hydrophilic trolox equivalent antioxidant capacity (H-TEAC) assay, while the lipophilic antioxidant capacity of the oil was measured using the α-TEAC assay. Chokeberry seeds exhibited a significant H-TEAC value of 20.5 ± 0.9 mmol TE/100 g dry weight (DW), and the oil demonstrated an antioxidant activity of 50.7 μmol α-TE/100 g. The nutrient composition and antioxidant properties of chokeberry seeds and their oil suggest they may offer health benefits to consumers. These findings highlight the potential of chokeberry seeds and oil as valuable sources for the development of new multi-purpose products in industries such as cosmetics, pharmaceuticals, and food.
***Key words**: seed oil, fatty acids, carotenoids, tocopherols*

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HEMIJSKA KARAKTERIZACIJA SEMENA ARONIJE I ULJA DOBIJENOG IZ NJEGA: SASTAV I POTENCIJALNI ZDRAVSTVENI ASPEKTI

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Plod aronije predstavlja bogat izvor bioaktivnih jedinjenja. Visoke koncentracije polifenola, poput fenolnih kiselina, flavonola, antocijanina, flavanola i proantocijanidina, igraju ključnu ulogu u njihovoj bioaktivnosti. Seme aronije, kao i ulje dobijeno iz njega, takođe može biti konzumirano, iako se retko nalazi kao sastojak prehrambenih proizvoda. Cilj ovog istraživanja bio je da ispita karakteristike i sastav nutrijenata semena aronije i odgovarajućeg ulja. Ulje je ekstrahovano primenom heksana kao rastvarača u Soxhlet ekstraktoru tokom 6 sati na 60°C. Pre analize, masne kiseline su prevedene u metil-estere masnih kiselina korišćenjem standardne procedure sa sumpornom kiselinom. Tokoferoli i tokotrienoli su analizirani primenom normalno-fazne HPLC tehnike sa fluorescentnim detektorom, dok su karotenoidi analizirani primenom normalno-fazne HPLC tehnike sa detektorom sa diodnim nizom. Ulje semena je pokazalo visok stepen nezasićenosti. Analiza gasnom hromatografijom utvrdila je da je glavna nezasićena masna kiselina alfa-linolenska kiselina (80,0%), praćena oleinskom kiselinom (10,4%). Glavna zasićena masna kiselina bila je palmitinska kiselina (5,2%). Takođe, pokazano je da je seme aronije bogato tokoferolima, pri čemu je α-tokoferol najzastupljeniji (21,7 mg/100 g semena), a sledi β-tokoferol (3,3 mg/100 g semena). Što se tiče tokotrienola, detektovan je samo γ-tokotrienol, sa sadržajem od 0,7 mg/100 g semena. HPLC analiza je takođe identifikovala karotenoide, pri čemu je (E)-β-karoten dominantan među njima (3,7 mg/100 g), nakon čega sledi lutein (1,2 mg/100 g). Antioxidantni kapacitet semena aronije procenjen je korišćenjem testa hidrofilnog trolox ekvivalenta antioskidativnog kapaciteta (H-TEAC), dok je lipofilni antioskidativni kapacitet ulja meren α-TEAC testom. Seme aronije je pokazalo značajnu vrednost od 20,5 ± 0,9 mmol TE/100 g suve mase (DW), dok je ulje pokazalo antioksidativnu aktivnost od 50,7 µmol α-TE/100 g. Rezultati sastava nutrijenata i antioksidantnih svojstava semena aronije i njegovog ulja ukazuju na to da pomenute sirovine mogu ostvariti zdravstvenu korist za potrošače. Ovo istraživanje ističe njihov potencijal kao vrednog izvora za razvoj novih funkcionalnih proizvoda u industrijama poput kozmetičke, farmaceutske i industrije hrane.

Ključne reči: *ulje semena, masne kiseline, karotenoidi, tokoferoli*

Zahvalnica: Ovaj rad je podržalo Ministarstvo za nauku, inovacije i tehnološki razvoj Republike Srbije ugovor broj 451-03-66/2024-03/200003.

COMPARISON OF THE NUTRITIONAL COMPOSITION OF MAIZE GRAIN UNDER DIFFERENT DRYING TREATMENTS

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The study of the nutritional properties of maize before and after drying allows the selection of optimal hybrids and varieties for different uses and helps to determine the most suitable drying method. The research included a comparison of traditional white and red maize varieties with modern hybrids and analyzed the effects of different drying methods – vacuum drying and fluidized bed drying – at temperatures of 70°C, 80°C and 90°C.

The results show that vacuum drying is more suitable than fluidized bed drying, although the drying speed in the fluidized bed is almost twice as high. Of all the samples, hybrid maize showed the best ability to release moisture and dried the fastest, while the traditional varieties were more resistant to moisture loss. In addition, the chemical composition of maize changes significantly depending on the drying process and temperature. The proportion of carbon (C), hydrogen (H), nitrogen (N) and sulfur (S) increased after vacuum drying at all temperatures tested.

Protein analysis showed that higher temperatures lead to a decrease in protein content, with the most effective treatment being vacuum drying at 70 °C, where most of the protein is retained. The starch content was the highest in the red maize variety in its natural state and retained the highest values after vacuum drying at 80°C for all varieties. In contrast, the fat content was the highest in the natural samples of hybrid maize, while it was the highest in the samples dried in a fluidized bed at 80°C and lowest in the samples treated in a vacuum at 90°C after processing.

A comparison of the nutrient composition showed that the values differed depending on the variety and drying method. The white maize variety had the highest protein content in its natural state and after drying in a vacuum and in a fluidized bed at 70°C. On the other hand, the hybrid maize retained the fattest after drying in a vacuum at 70°C, while the red variety had the highest starch content after drying in a vacuum at 70°C and in a fluidized bed at 80°C.

These results suggest that the new hybrids are more suitable for processing and industrial processing due to their better resistance to moisture loss and faster drying. Nevertheless, the nutritional values of the hybrids and the traditional varieties remained comparable, suggesting that the traditional varieties can maintain their nutritional value despite the lower efficiency of the drying process.

These studies allow for a more accurate determination of optimal temperatures and drying methods for different uses of maize, which can improve the quality of the final product and increase processing efficiency. Further studies should focus on the analysis of other technological parameters that can further optimize the drying process and improve the nutritional value of corn.

***Key words**: drying methods, traditional maize varieties, technological optimization*

USPOREDBA NUTRITIVNOG SASTAVA ZRNA KUKURUZA PRIMJENOM RAZLIČITIH TRETMANA SUŠENJA

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Proučavanje hranjivih svojstava kukuruza prije i poslije sušenja omogućuje odabir optimalnih hibrida i sorti za različite namjene te pomaže u određivanju najprikladnijeg načina sušenja. Istraživanja su uključivala usporedbu tradicionalnih sorti bijelog i crvenog kukuruza sa suvremenim hibridima te analizirali učinke različitih metoda sušenja – sušenja u vakuumu i sušenja u fluidiziranom sloju – na temperaturama od 70°C, 80°C i 90°C.

Rezultati pokazuju da je vakuumsko sušenje prikladnije od sušenja u fluidiziranom sloju, iako je brzina sušenja u fluidiziranom sloju gotovo dvostruko veća. Od svih uzoraka hibridni kukuruz je pokazao najbolju sposobnost otpuštanja vlage i najbrže se osušio, dok su tradicionalne sorte bile otpornije na gubitak vlage. Osim toga, kemijski sastav kukuruza značajno se mijenja ovisno o procesu sušenja i temperaturi. Udio ugljika (C), vodika (H), dušika (N) i sumpora (S) povećava se nakon vakuumskog sušenja na svim ispitanim temperaturama.

Analiza bjelančevina pokazala je da više temperature dovode do smanjenja udjela bjelančevina, pri čemu je najučinkovitiji tretman sušenje u vakuumu na 70 °C, gdje se zadržava većina bjelančevina. Udio škroba bio je najveći u sorti crvenog kukuruza u prirodnom stanju, a zadržao je najviše vrijednosti nakon vakuumskog sušenja na 80°C za sve sorte. Nasuprot tome, udio masti bio je najveći u prirodnim uzorcima hibrida kukuruza, dok je bio najveći u uzorcima sušenim u fluidiziranom sloju na 80°C, a najmanji u uzorcima tretiranim u vakuumu na 90°C nakon obrade.

Usporedba sastava hranjiva pokazala je da se vrijednosti razlikuju ovisno o sorti i načinu sušenja. Sorta bijelog kukuruza imala je najveći sadržaj proteina u prirodnom stanju te nakon sušenja u vakuumu i fluidiziranom sloju na 70°C. S druge strane, hibridni kukuruz zadržao je najviše masti nakon sušenja u vakuumu na 70°C, dok je crvena sorta imala najveći sadržaj škroba nakon sušenja u vakuumu na 70°C i u fluidiziranom sloju na 80°C.

Ovi rezultati sugeriraju da su novi hibridi prikladniji za doradu i industrijsku preradu zbog bolje otpornosti na gubitak vlage i bržeg sušenja. Unatoč tome, nutritivne vrijednosti hibrida i tradicionalnih sorti ostale su usporedive, što ukazuje na to da tradicionalne sorte mogu zadržati svoju nutritivnu vrijednost unatoč nižoj učinkovitosti procesa sušenja.

Ova istraživanja omogućuju točnije određivanje optimalnih temperatura i metoda sušenja za različite namjene kukuruza, što može poboljšati kvalitetu konačnog proizvoda i povećati učinkovitost prerade. Daljnja istraživanja trebala bi se usmjeriti na analizu drugih tehnoloških parametara koji mogu dodatno optimizirati proces sušenja i poboljšati hranjivu vrijednost kukuruza.

Ključne riječi: *metode sušenja, tradicionalne sorte kukuruza, tehnološka optimizacija*

MEASURING THE PRODUCTIVITY CHANGE IN SERBIAN FARMS USING FADN DATA

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Ensuring a fair income for farmers and increasing competitiveness are identified as key objectives of the Common Agricultural Policy, seamlessly integrated into the strategic plans of European countries for the 2023-2027 period. Achieving these goals is also very important for ensuring the economic viability of farms. Agricultural activity is currently unattractive, mainly due to the low average income of farmers. Meanwhile, small family farms, which are the most prevalent, face challenges in competing with larger farms in the market. Improving the efficiency or productivity of the production process would have positive implications for economic outcomes, farmers' average income, and, simultaneously, the overall economic viability of farms. For this reason, the aim of the research is to identify and assess the change in productivity level across farms with different types of production. The focus of the research is on family farms in the Republic of Serbia that were part of the FADN (Farm Accountancy Data Network) sample over a seven-year period (2015-2021). The paper applies the Total Factor Productivity (TFP) method, in conjunction with previously used Data Envelopment Analysis (DEA). The defined model is input-oriented with variable returns to scale. On the output side, it considers the value of production, while the input side includes multiple variables: labour input, utilized agricultural area, intermediate consumption and total asset value. The productivity change of farms is measured using the Malmquist TFP index. The research results have shown that the total factor productivity of the observed farms increased by 8.5% over the analyzed seven-year period. The increase in farm productivity ranges from 0.3% in specialist permanent crops (wine and fruit) to 11.8% in specialist field crops. Recently, field crop farms have been acquiring new and modern equipment that enables them to achieve the same or even better results with less labour input. They have access to various domestic and European funds, which play significant role in co-financing the purchase of higher-performance equipment. This, of course, has a positive effect on farm productivity, i.e., on the higher efficiency of production process, which undoubtedly increases the level of economic viability of farms.

Key words: *total factor productivity, economic viability, family farms, type of production, FADN.*

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PROMENA U PRODUKTIVNOSTI POLJOPRIVREDNIH GAZDINSTAVA U SRBIJI NA OSNOVU FADN PODATAKA

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Osiguranje fer životnog standarda poljoprivrednika i povećanje njihove konkurentnosti na tržištu svrstavaju se među primarne ciljeve Zajedničke agrarne politike (eng. Common Agricultural Policy), koji su ujedno inkorporirani u strateške planove evropskih zemalja za period od 2023. do 2027. godine. Ispunjenje ovih ciljeva veoma je važno i za dostizanje ekonomske održivosti poljoprivrednih gazdinstava. Poljoprivredna delatnost trenutno nije atraktivna prevashodno zbog niskog prosečnog dohotka poljoprivrednika. Takođe, mala porodična gazdinstva, koja su i najbrojnija, nisu konkurentna velikim gazdinstvima na tržištu. Povećanje efikasnosti odnosno produktivnosti procesa proizvodnje imalo bi pozitivne implikacije na ostvarene ekonomske rezultate, prosečan dohodak poljoprivrednika, a ujedno i na ukupnu ekonomsku održivost poljoprivrednih gazdinstava. Upravo zbog toga, cilj istraživanja je da se realno sagleda i oceni promena u produktivnosti poljoprivrednih gazdinstava različitih tipova proizvodnje. U fokusu istraživanja su porodična poljoprivredna gazdinstva u Republici Srbiji, koja su bila deo FADN (eng. Farm Accountancy Data Network) uzorka tokom sedmogodišnjeg perioda (2015-2021). U radu je korišćen metod ukupne faktorske produktivnosti (eng. Total Factor Productivity - TFP), uz prethodnu primenu DEA metoda (eng. Data Envelopment Analysis). Definisani model je ulazno orijentisan (eng. input-oriented) sa promenljivim prinosom na obim (eng. variable returns to scale), pri čemu je na strani autputa vrednost proizvodnje, dok na strani inputa figurira više varijabli: korišćena radna snaga, ukupno korišćeno poljoprivredno zemljište, ukupna međufazna potrošnja i ukupna imovina poljoprivrednog gazdinstva. Promena u produktivnosti gazdinstava iskazana je pomoću Malmquist TFP indeksa. Rezultati istraživanja pokazuju da je ukupna faktorska produktivnost posmatranih gazdinstava povećana za 8,5% u analiziranom sedmogodišnjem periodu. Povećanje produktivnosti gazdinstava varira od 0,3%, koliko je zabeleženo u voćarstvu i vinogradarstvu, do 11,8% zabeleženih u ratarstvu. Ratarska gazdinstva se u poslednje vreme opremaju novom i savremenom mehanizacijom, koja im omogućuje ostvarivanje istih ili boljih rezultata uz manje ulaganje ljudskog rada. Na raspolaganju su im razni domaći i evropski fondovi, koji značajno učestvuju u sufinansiranju nabavke nove opreme velikog radnog učinka. Ovo naravno pozitivno utiče na ostvarenu produktivnost gazdinstava, odnosno na veću efikasnost procesa proizvodnje, što svakako podiže i nivo ekonomske održivosti gazdinstava.

Ključne reči: *ukupna faktorska produktivnost, ekonomska održivost, porodična gazdinstva, tip proizvodnje, FADN.*

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PANEL REGRESSION ANALYSIS OF PROFITABILITY FACTORS OF OIL PRODUCTION COMPANIES FROM THE REPUBLIC OF SERBIA

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Oilseed production has traditionally been present in agricultural production in the Republic of Serbia. Given the strong connection between the agricultural and food industries, oil production represents a significant segment of the Serbian food industry. As with other production lines, the stability and profitability of oil producers depend on a variety of factors. These factors are generally divided into microeconomic factors, which are under the control of companies, and macroeconomic factors, which reflect the economic environment in which a company operates. This study analyzes the factors influencing the profitability of oil production companies (industry classification code 10.41) in the Republic of Serbia over the period from 2014 to 2023. Profitability is measured using the return on assets (ROA), while the examined microeconomic factors include the strict liquidity ratio, debt ratio, revenue per employee, and asset turnover ratio. The analyzed macroeconomic factors are the gross domestic product (GDP) growth rate and inflation. The research is based on financial data from 20 companies registered as oil producers in Serbia. The data analysis begins with a descriptive statistical analysis, followed by the application of a panel regression model to determine the impact of selected microeconomic and macroeconomic factors on the profitability of the observed companies. Prior to conducting the panel regression analysis, a series of tests was performed to assess the suitability of this statistical method, including tests for multicollinearity, autocorrelation, heteroskedasticity, and dependence of comparative data. The results of the fixed-effects panel regression model (with robust standard errors) indicate that among the microeconomic factors, the strict liquidity ratio, debt ratio, and asset turnover ratio have a statistically significant impact on profitability. Among the macroeconomic factors, inflation emerged as a significant determinant. Among the identified significant factors, only the asset turnover ratio had a statistically significant and positive effect on profitability, while the strict liquidity ratio, debt ratio, and inflation had statistically significant negative effects.
These findings can be valuable for company managers and decision-makers in the food industry, particularly in terms of the importance of managing a company's financial structure to ensure sustainable and profitable operations.
Key words**:** *profitability, oil production, panel regression, financial indicators, inflation, debt ratio, asset turnover ratio.*

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PANEL REGRESIONA ANALIZA FAKTORA PROFITABILNOSTI PREDUZEĆA ZA PROIZVODNJU ULJA IZ REPUBLIKE SRBIJE

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Proizvodnja uljarica tradicionalno je zastupljena u poljoprivrednoj proizvodnji u Republici Srbiji, s obzirom na povezanost poljoprivredne i prehrambene industrije, proizvodnja ulja predstavlja značajan segment u prehrambenoj industriji Republike Srbije. Kao i u slučaju drugih linija proizvodnje, i stabilnost i profitabilnost proizvođača ulja zavise od niza faktora. Ovi faktori se najčešće dele na mikroekonomske, koji su pod kontrolom samih preduzeća i makroekonomske, koji su pokazatelji privrednog ambijenta u kojem preduzeće posluje. U ovom istraživanju analizirani su faktori od uticaja na profitabilnost preduzeća koja se bave proizvodnjom ulja (šifra delatnosti 10.41) u Republici Srbiji, u periodu od 2014. do 2023. godine. Kao pokazatelj profitabilnosti posmatran je racio obrta ukupne poslovne imovine (ROA), kao mikroekonomski faktori posmatrani su rigorozni racio likvidnosti, koeficijent zaduženosti, prihodi po zaposlenom i racio obrta ukupnih poslovnih sredstava, a kao makroekonomski faktori posmatrani su stopa rasta bruto domaćeg proizvoda i inflacija. Analizirani su podaci iz finansijskih izveštaja za 20 preduzeća koja su registrovana kao proizvođači ulja u Republici Srbiji. Analiza podataka započeta je primenom deskriptivne statističke analize, a zatim je primenjen panel regresioni model kako bi se utvrdio uticaj odabranih mikroekonomskih i makroekonomskih faktora na profitabilnost posmatranih preduzeća. Pre sprovođenja panel regresione analize sproveden je i niz testova kako bi se ocenila adekvatnost primene ovog statističkog metoda, tj. sprovedeni su testovi za testiranje postojanja multikolinearnosti, autokorelacije, heteroskedastičnosti i zavisnosti uporednih podataka. Rezultati primenjenog panel regresionog modela sa fiksnim efektima (sa robusnim standardnim greškama) utvrđeno je da od mikroekonomskih faktora statistički značajan uticaj na profitabilnost posmatranih preduzeća imaju rigorozni racio likvidnosti, koeficijent zaduženosti i raco obrta ukupne imovine, dok od makroekonomskih faktora kao značajan faktor izdvojila se inflacija. Od utvrđenih značajnih faktora statistički značajan i pozitivan uticaj na profitabilnost posmatranih preduzeća imao je samo racio obrta ukupne poslovne imovine, a statistički značajan i negativan uticaj imali su rigorozni racio likvidnosti, koeficijent zaduženosti i inflacija. Dobijeni rezultati mogu biti od značaja menadžerima preduzeća i donosiocima odluka u prehrambenoj industriji, naročito u pogledu važnosti upravljanja finansijskom strukturom preduzeća.

Ključne reči: *profitabilnost, prehrambena preduzeća, panel regresiona analiza, proizvodnja ulja.*

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YIELD OF EARLY POTATOES IN THE CONDITIONS OF WESTERN SERBIA

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The production of early potatoes represents a good opportunity for making a profit, because it arrives early in the spring when there is not a large selection of fresh vegetables on the market and, as a rule, have a good price. Here, there are very favorable conditions for the production of early potatoes, which agricultural producers do not use. With relatively low investments, early maturity of early potatoes can be achieved by applying the following agrotechnical measures: selection variety, sprouting of planting material, early planting, improvement of thermal conditions (selection location, use of agrorotextiles and mulch foils). Early potatoes are harvested very early (mid-May) and allow two harvests a year, leaving behind a well-structured soil with a high level of nutrients. The application of protective agents can be completely omitted or reduced to a minimum, so that a product that is safe for health is obtained. The great agrotechnical importance of new potatoes is also reflected in the fact that they are grown in crop rotation.

The goal of the research was to determine the variation in the yield of early potatoes in the conditions of western Serbia. During 2021 and 2022, the experiment was carried out at the site of KO Bogatić, the area of the village of Belotić (65 m above sea level, chernozem), 44˚ 49' N, 19˚ 32' E. The research was set up with three potato varieties: one early (Colomba) and two medium early (Esmee and Memphis). The field experiment was carried out as a two-factorial split-plot method in four replications. Planting in both years was set up (March 15), the distance between the rows was 0.70 m, and the distance in the row was 0.30 m. Harvesting of early potato tubers and assessment of productivity performed on June 30 in both years of the research.

The analysis of productive traits showed very significant differences ($r<0.01$) and ($r<0.05$) under the influence of the variety (factor G). The influence of the year (factor E) and the interaction of factors (E × G) on the examined productive traits of early potatoes were absent. A significantly higher number of tubers per plant was recorded in the Colombo variety in both years of testing, compared to the Esmee and Memphis varieties. In the two-year average, the largest tubers of 88.00 g were recorded with the Memphis, followed by 68.50 g with the Esmee, while the smallest tubers with an average of 65.0 g were recorded with the Colomba. The mid-early varieties Esmee and Memphis showed a significantly lower yield of early potatoes, compared to the early variety Colombo. A significant positive correlation was found between the yield of new potatoes and the number of tubers per plant ($r = 0.78447$, $p<0.05$). We can conclude that the Colomba variety, due to its early maturity and genetic predisposition, formed and bulking the tubers the fastest, which directly influenced the achievement of the highest yield of early potatoes.

***Key words**: variety, number of tubers.*

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PRINOS MLADOG KROMPIRA U USLOVIMA ZAPADNE SRBIJE

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Proizvodnja mladog krompira predstavlja dobru mogućnost za ostvarivanje profita, jer stiže rano u proleće kada na tržištu nema veliki izbor svežeg povrća i po pravilu postiže dobru cenu. Kod nas postoje veoma povoljni uslovi za proizvodnju mladog krompira koju poljoprivredni proizvođači ne koriste. Uz relativno niska ulaganja može se postići ranije dospevanje mladog krompira primenom sledećih agrotehničkih mera: izbor sorte, naklijavanje sadnog materijala, rana sadnja, poboljšanje toplotnih uslova (izbor lokacije, upotreba agrorotekstila i malč folija).
Mladi krompir se vadi veoma rano (već polovinom maja) i omogućava dve žetve u godini, ostavljajući iza sebe zemljište dobre strukture sa visokim nivoom hraniva. Primena sredstava zaštite može se potpuno izostaviti ili svesti na minimum, tako da se dobija proizvod koji je zdravstveno bezbedan. Takođe veliki agrotehnički značaj mladog krompira ogleda se i u tome što se gaji u plodoredu.
Cilj istraživanja bio je da se utvrdi variranje prinosa mladog krompira u uslovima zapadne Srbije. Tokom 2021. i 2022. godine, ogled je izveden na lokalitetu KO Bogatić, područje sela Belotić (65 m nv., černozem), 44˚ 49' N, 19˚ 32' E. Istraživanja je izvedeno sa tri sorte krompira: jedne rane (Colomba) i dve srednje rane (Esmee i Memphis). Poljski ogled izveden je kao dvofaktorijalni metodom podeljenih parcela u četiri ponavljanja. Sadnja u obe godine izvedena je (15. marta), rastojanje između redova bilo je 0,70 m, a rastojanje u redu 0,30 m. Vađenje krtola mladog krompira i ocena produktivnosti izvršena 30.06. u obe godine istraživanja.
Analiza produktivnih osobina pokazala je vrlo značajne razlike ($p<0,01$) i ($p<0,05$) pod uticajem sorte (factor G). Uticaj godine (factor E) i interakcije faktora (E × G) na ispitivane produktivne osobine mladog krompira je izostao. Kod sorte Colomba u obe godine ispitivanja zabeležen je značajno veći broj krtola po biljci, u odnosu na sorte Esmee i Memphis, što je imalo rezultat obrnutu situaciju kada je u pitanju osobina prosečna masa krtole po biljci. U dvogodišnjem proseku najkrupnije krtole od 88,00 g zabeležene su kod sorte Memphis, zatim 68,50 g kod sorte Esmee, dok su najsitnije krtole u proseku od 65,0 g zabeležene su kod sorte Colomba. Kod srednje ranih sorti Esmee i Memphis konstatovan je značajno manji prinos mladog krompira, u poređenju sa ranom sortom Colomba. Utvrđena je značajna pozitivna korelacija između prinosa mladog krompira i broja krtola po biljci ($r = 0.78447$, $p<0.05$). Sve tri sorte su ostvarile visoke prinose mladog krompira. Možemo zaključiti da je sorta Colomba zbog svoje ranostasnosti i genetske predispozicije najbrže formirala i nalivala krtole, što je direktno uticalo da ostvari i najveći prinos mladog krompira.
Ključne reči: *sorta, broj krtola.*

Zahvalnica: Ministarstvo obrazovanja, nauke i tehnološkog razvoja Republike Srbije, Ugovor br. 451-03-66/2024-03/ 200010.

BIOLOGICAL PROPERTIES OF FRESH CREAM CHEESE WITH THE ADDITION OF SELECTED PLANT SPECIES

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The aim of this work was to examine the influence of the addition of selected plant species on the biological (antioxidant and antimicrobial) properties of fresh cream cheese. In the milk processing plant, six samples of cheese were produced, one of which was a control sample without additives and five samples with the addition of 1% oregano (*Origanum vulgare*), basil (*Ocimum basilicum*), parsley (*Petroselinum crispum*), rosemary (*Rosmarimus officianalis*) and chives (*Allium schoenoprasum*). The determination of the content of total phenols, non-flavonoids, flavonoids, as well as the determination of antioxidant activity by FRAP, DPPH and ABTS test was carried out. Antimicrobial testing of cheese extracts was performed using the agar dilution method, on four types of bacteria (*Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus and Bacillus cereus*) and two strains of *Candida albicans*. Based on the obtained results, it was determined that the addition of selected plant species has a statistically significant ($p<0.05$) effect on increasing the content of phenolic compounds in the tested cheeses. The control sample had the lowest content of total phenols (57.43 μg GAE/g), flavonoids (7.09 μg GAE/g) and non-flavonoids (50.34 μg GAE/g), while cream cheese samples with the addition of 1% oregano had the highest content of total phenols (1118.48 μg GAE/g), flavonoids (251.50 μg GAE/g) and non-flavonoids (866.98 μg GAE/g). In the other tested samples, the content of total phenols ranged from 280.90 μg GAE/g (cheese with added chives) to 548.22 μg GAE/g (cheese with added basil), the content of flavonoids was 56.69 μg GAE/g g in cheese with the addition of parsley up to 169.20 μg GAE/g in cheese with the addition of basil, and the content of non-flavonoids was from 220.31 μg GAE/g in cheese with added chives, up to 379.02 μg GAE/g in cheese with added basil. The FRAP, DPPH and ABTS test also confirmed that the addition of selected plant species statistically significantly ($p<0.05$) affects the increase in the antioxidant activity of the tested cheeses. The sample with the addition of oregano had the highest antioxidant capacity of 7.46 μmol Fe^{2+}/g (FRAP test), 2.97 μmol TE/g sample (DPPH test) and 5.11 μmol TE/g (ABTS test). The FRAP test also found that the samples with the addition of basil and rosemary had high values (4.95 μmol Fe^{2+}/g and 5.51 μmol Fe^{2+}/g), while the cheeses with the addition of chives and parsley showed lower values (0.73 μmol Fe^{2+}/g and 0.87 μmol Fe^{2+}/g). All tested cheese extracts did not show antimicrobial activity. Based on the obtained results, it can be concluded that the selected plant species, with a high content of phenolic compounds, especially oregano, basil, and rosemary, represent a potential source of natural antioxidants with possible application in the production of fresh cream cheese.

Key words: *cheese, plant species, biological properties.*

BIOLOŠKA SVOJSTVA SVJEŽEG KREM SIRA SA DODATKOM ODABRANIH BILJNIH VRSTA

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Cilj ovog rada je bio ispitati uticaj dodatka odabranih biljnih vrsta na biološka (antioksidativna i antimikrobna) svojstva svježeg krem sira. U pogonu za preradu mlijeka je proizvedeno šest uzoraka sira od kojih je jedan kontrolni uzorak, bez dodataka i pet uzoraka sa dodatkom 1% origana (*Origanum vulgare)*, bosiljka *(Ocimum basilicum)*, peršuna (*Petroselinum crispum)*, ruzmarina *(Rosmarimus officianalis)* i vlasca (*Allium schoenoprasum).* Vršeno je određivanje sadržaja ukupnih fenola, neflavonoida, flavonoida, kao i određivanje antioksidativne aktivnosti FRAP, DPPH i ABTS testom. Antimikrobno testiranje ekstrakata sireva vršeno je metodom razrjeđivanja u agaru, na četiri vrste bakterija (*Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus* i *Bacillus cereus*) i dva soja *Candida albicans*. Na osnovu dobijenih rezultata utvrđeno je da dodatak odabranih biljnih vrsta statistički značajno ($p<0,05$) utiče na povećanje sadržaja fenolnih jedinjenja u ispitivanim sirevima. Kontrolni uzorak je imao najmanji sadržaj ukupnih fenola (57,43 µg GAE/g), flavonoida (7,09 µg GAE/g) i neflavonoida (50,34 µg GAE/g), dok su uzorci krem sira sa dodatkom 1% origana imali najveći sadržaj ukupnih fenola (1118,48 µg GAE/g), flavonoida (251,50 µg GAE/g) i neflavonoida (866,98 µg GAE/g). U ostalim ispitivanim uzorcima sadržaj ukupnih fenola se kretao od 280,90 µg GAE/g (sir sa dodatkom vlasca), do 548,22 µg GAE/g (sir sa dodatkom bosiljka), sadržaj flavonoida je iznosio od 56,69 µg GAE/g u siru sa dodatkom peršuna do 169,20 µg GAE/g u siru sa dodatkom bosiljka, a sadržaj neflavonoida je iznosio od 220,31 µg GAE/g u siru sa dodatkom vlasca, do 379,02 µg GAE/g u siru sa dodatkom bosiljka. FRAP, DPPH i ABTS testom je takođe potvrđeno da dodatak odabranih biljnih vrsta statistički značajno ($p<0,05$) utiče na povećanje antioksidativne aktivnosti ispitivanih sireva. Uzorak sa dodatkom origana je imao najveću antioksidativnu sposobnost i to 7,46 µmol Fe^{2+}/g (FRAP test), 2,97 µmol TE/g uzorka (DPPH test) i 5,11 µmol TE/g (ABTS test). FRAP testom je takođe utvrđeno da su i uzorci sa dodatkom bosiljka i ruzmarina imali visoke vrijednosti (4,95 µmol Fe^{2+}/g i 5,51 µmol Fe^{2+}/g), dok sirevi sa dodatkom vlasca i peršuna su pokazali niže vrijednosti (0,73 µmol Fe^{2+}/g i 0,87 µmol Fe^{2+}/g). Svi testirani ekstrakti sireva nisu ispoljili antimikrobnu aktivnost. Na osnovu dobijenih rezultata može se zaključiti da odabrane biljne vrste, sa visokim sadržajem fenolnih jedinjenja, naročito origano, bosiljak i ruzmarin predstavljaju potencijalni izvor prirodnih antioksidanasa sa mogućom primjenom u proizvodnji svježeg krem sira.

***Key words**: sir, biljne vrste, biološka svojstva.*

VITALITY OF PUMPKIN SEEDS FROM DIFFERENT REGIONS DURING A THREE-YEAR STORAGE PERIOD

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Pumpkins are annual plants native to Central and South America, but are grown and consumed worldwide. They belong to the genus Cucurbita of the Cucurbitaceae family. In the World, all parts of the plant are edible: seeds, flowers, roots, leaves and fruits. In Serbia, there is a tradition of using fruits and seeds in the diet.
Pumpkins with a long tradition in the nutrition of people and animals in Serbia. However, in past decades it was considered food for the poor.
During the last decades, pesticides have been widely applied in agriculture. On the other hand, in the production of pumpkins, pesticides are not applied, so it has become a sought-after and valued food. This is supported by recent research, which found that pumpkins are good in a diet of people with high blood sugar and hypertension.
However, in order to obtain fruits, seeds or other edible parts of pumpkins, it is necessary to use seeds of the best possible quality to establish the optimal crop stand, and yield.
The quality of the seeds is highly dependent on the moisture content during harvesting and the environmental conditions in which the seeds are stored: the atmospheric humidity, the packaging in which the seeds are stored, the storage temperature, and as well on the structure of the seed, which conditions it, plant species, variety or population, i.e. everything that is influenced by genetics.
The research showed the variability of seed vitality (germination energy and total germination) from four localities (seed-batch factor) and ages of 1, 2, and 3 years (seed age factor).
Research has shown that germination energy and total germination were significantly influenced by the fact of seed origin and the factor of seed age and their interaction (seed origin-batch x seed age), ($p \leq 0.05$ to $p \leq 0.01$)
Key words: *age, pumpkin, origin, seed quality.*

KVALITET SEMENA TIKAVA IZ RAZLIČITIH REGIONA TOKOM TROGODIŠNJEG PERIDA ČUVANJA

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Bundeve su jednogodišnje biljke koje potiču iz Centralne i južne Amerike, ali se uzgajaju i konzumiraju širom sveta. Pripadaju rodu Cucurbita porodice Cucurbitaceae. U Svetu su svi delovi biljke jestivi: semenke, cvetovi, koreni, listovi i plodovi. U Srbiji je tradicija korišćenja u ishrani plodova i semenki.

Bundeve sa dugom tradicijom u ishrani ljidi i životinja u Srbiji. Međutim u prošlim decenijama to se smatrala hranom za siromašne.

U toku zadnje decenija u poljoprivredi se mnogo primenjuju pesticidi. Na suprot u proizvodnji bundeva pesticida se ne primenjuju pa je to postala tražena i cenjena hrana. Tome doprinose novija istraživanjima u kojima je utvrđeno da su tikve dobre u ishrani ljudi koji su sa povišenim šećerom i hipertenzijom.

Međutim da bi se došlo do plodova, semena ili drugih jestivih delova tikava potrebno je za zasnivanje useva koristiti seme što boljeg kvaliteta.

Kvalitet semena u visokoj je zavisnosti od sadržaja vlage pri ubiranju i ambijentalnih uslova u kojima se čuva seme: vlažnošću atmosfere, ambaleže u kojoj je seme skladišteno, temperature skladištenja, ali i od građe semena što uslovljava, biljna vrsta, sorta ili populacija, odnosno sve ono što je pod uticajem genetike.

U istraživanjima je prikazana varijabilnost kvaliteta semena (energije klijanja i ukupna klijavost) sa četiri lokaliteta (faktot poreklo semena-partija) i starosti 1, 2, i 3 godine (faktor starost semena).

Istraživanja su pokazala da je na energiju klijanja i ukupnu klijavost značajno uticao faktot poreklo semena i faktor starost semena i nihova interakcija (poreklo semena-partija x starost semena), ($p \leq 0.05$ do $p \leq 0.01$).

Ključne reči: *bundeva, kvalitet semena, poreklo, starost.*

RESPECT AND CARE FOR TRADITIONAL UNDERSTANDINGS OF AGROBIODIVERSITY

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The advancement of sustainable agriculture is closely linked to the preservation of traditional values. A modern strategy for promoting sustainability in primary agriculture supports the integration of science and practice. This involves involving citizens in various research projects and raising community awareness of the importance of preserving natural resources. With the technological development of society, modern agriculture has moved away from natural laws by introducing hybridization and the creation of new varieties on a genetically narrow basis, which has led to natural diversity loss. The primary framework of Citizen Science is the engagement of community members in research activities, which include the collection and monitoring of plant species and the encouragement of citizen science initiatives such as seed sharing and the development of seed databases, ensuring future generations access to a wide range of different information about the natural potential of the region. The main challenge in involving farmers in scientific research and development of food production technologies is the effective engagement of the wider community in the problem of biodiversity loss and the conservation of natural resources. Agriculture is intrinsically linked to global and local food production systems. This affects food security, climate change, environmental sustainability and issues of social justice. From the perspective of sustainable agriculture, it builds sovereignty and development of rural communities. The concept of citizen science is part of the process of creating new research methodologies that harmonize scientific research with traditional practices within the framework of sustainable development. The ultimate goal of these activities is to strengthen the awareness and initiative of citizens in the fight for biodiversity conservation. These methodologies not only empower local populations, but also encourage the preservation of indigenous knowledge, which is vital for solving contemporary challenges. Integrating citizen science into agricultural practices can create a comprehensive framework for combating climate change and food security.
***Key words**: biodiversity, citizen science, sustainability.*

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POŠTOVANJE I BRIGA O TRADICIONALNOM SHVATANJU AGROBIODIVERZITETA

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Unapređenje održive poljoprivrede usko je povezano sa očuvanjem tradicionalnih vrednosi . Moderna strategija za podsticanje održivosti u primarnoj poljoprivredi podržava integraciju nauke i prakse. Ovo podrazumeva uključivanje građana u različite istraživačke projekte i podizanje svesti zajednice o važnosti očuvanja prirodnih resursa. Sa tehnološkim razvojem društva, moderna poljoprivredna se udaljila od prirodnih zakona uvodeći hibridizaciju i stvaranje novih sorti na genetski uskim osnovama, što je dovelo do procesa gubitka prirodne raznolikosti. Primarni okvir građanskih istraživanja je angažovanje članova zajednice u istraživačkim aktivnostima, koje uključuju prikupljanje i praćenje biljnih vrsta i podsticanje građanskih naučnih inicijativa kao što su deljenje semena i razvoj baze podataka o semenu, osiguravajući budućim generacijama pristup širokom spektru različitih informacija o prirodnim potencijalima regiona. Glavni izazov u uključivanju građana u naučna istraživanja i razvoj tehnologija proizvodnje hrane je efektivno angažovanje šire zajednice u problem gubitka prirodne raznovrsnosti i očuvanju i prirodnih resursa. Poljoprivreda je suštinski povezana sa globalnim i lokalnim sistemima proizvodnje hrane. Ovo utiče na bezbednost hrane, klimatske promene, održivost životne sredine i pitanja socijalne pravde. Iz perspektive održive poljoprivrede, ona gradi suverenitet i razvoj ruralne zajednice. Koncept građanske nauke deo je procesa kreiranja novih istraživačkih metodologija koje usklađuju naučno istraživanje sa tradicionalnom praksom u okviru održivog razvoja. Krajnji cilj ovih aktivnosti je jačanje svesti i inicijativa građana u borbi za očuvanje biodiverziteta.
Ove metodologije ne samo da osnažuju lokalno stanovništvo, već i podstiču očuvanje domorodačkog znanja, što je od vitalnog značaja za rešavanje savremenih izazova. Integrisanje nauke o građanima u poljoprivredne prakse može stvoriti sveobuhvatan okvir za borbu protiv klimatskih promena i bezbednosti hrane.
***Ključne reči**: biodiversitet, građanska istraživanja, održivost.*

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SAGE ESSENTIAL OIL EXHIBITS ANTIOXIDATIVE AND ANTIMICROBIAL ACTIVITY IN CHICKEN COOKED SAUSAGES

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Cooked sausages made of different kinds of meat (pork, chicken, beef), mechanically separated meat, fat tissue, water, salts, spice mixtures and additives represent one of the most popular meat products in Serbia. Microbiological contamination and lipid oxidation are one of the most frequent causes of cooked sausage deterioration. Lipid oxidation affects rancidness, discoloration as well as accumulation of potentially toxic compounds that are adverse to human health.

One way to retard the lipid oxidation is the addition of synthetic or natural antioxidants. Since synthetic antioxidants and preservativs have toxic and carcinogenic properties and present a potential health hazard to consumers, in the past few years the interest of researchers for natural antioxidants isolated from different plant materials (essential oil and extracts) rapidly increased.

Sage (*Salvia officinalis* L.) represents medicinal plant from *Lamiaceae* family, which has been recognized for various biological activities due to its complex chemical profile. Besides widely used application in the pharmaceutical industry, sage has found application as a flavoring agent in food products.

The effect of sage essential oil (SEO) obtained from sage (*Salvia officinalis* L.) on antioxidative and antimicrobial activity in chicken cooked sausages was investigated. pH, instrumental parameters of color (*CIE L**, *CIE a** and *CIE b**), thiobarbituric acid-reactive substance (TBARS) value, microbial profile and sensory panel scores were examined. The addition of SEO in concentrations from 0.010 to 0.100 µl/g significantly ($p<0.05$) affected the color of the product by reducing lightness (*CIE L**) and increasing redness (*CIE a**). The inclusion of SEO in concentrations of 0.075 and 0.100 µL/g significantly ($p<0.05$) reduced the lipid oxidation by TBARS test. All five tested concentrations of SEO resulted in significant ($p<0.05$) inhibition of microbial growth. This study shows that the sage essential oil could be used in processing of chicken cooked sausages in order to improve lipid oxidative and microbial stability as well as to enhance their color characteristics, without negative implications on odor and flavor of the final products.

Key words*: sage essential oil; cooked sausage; novel antioxidants; antimicrobial activity.*

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ETARSKO ULJE ŽALFIJE POKAZUJE ANTIOKSIDATIVNU I ANTIMIKROBNU AKTIVNOST U BARENIM KOBASICAMA OD PILEĆEG MESA

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Barene kobasice proizvode se od različitih vrsta mesa (svinjetina, piletina, govedina), mehanički separisanog mesa, masnog tkiva, vode, soli, mešavina začina i aditiva i predstavljaju jedan od najpopularnijih proizvoda od mesa u Srbiji. Mikrobiološka kontaminacija i oksidacija lipida su jedan od najčešćih uzročnika kvara ovih proizvoda. Oksidacija lipida utiče na pojavu užeglosti, promene boje, kao i na akumulaciju potencijalno toksičnih jedinjenja koja su štetna po ljudsko zdravlje.

Jedan od načina da se uspori oksidacija lipida je dodavanje sintetskih i prirodnih antioksidanasa. S obzirom da sintetski antioksidansi i konzervansi imaju toksična i prokancerogena svojstva i predstavljaju potencijalnu opasnost po zdravlje potrošača, interesovanje istraživača za izučavanje prirodnih antioksidanasa izolovanih iz različitog biljnog materijala (etarska ulja i ekstrakti) u poslednjih nekoliko godina rapidno je poraslo.

Žalfija (*Salvia officinalis* L.) je lekovita biljka iz porodice *Lamiaceae*, koja je poznata po širokom spektru bioloških aktivnosti, pre svega, zahvaljujući svom složenom hemijskom profilu. Pored široke primene u farmaceutskoj industriji, žalfija se koristi i kao začinsko biljka u prehrambenoj industriji.

U ovom radu ispitan je etarskog ulja (SEO) dobijenog iz žalfije (*Salvia officinalis* L.) na antioksidativnu i antimikrobnu aktivnost u barenim kobasicama od pilećeg mesa. U tu svrhu korišćeni su sledeći parametri: pH vrednost, instrumentalni parametri boje (*CIE L**, *CIE a** i *CIE b**), TBARS vrednost, mikrobiološki profil i ocene senzorskog panela. Aplikacija SEO u koncentracijama od 0,010 do 0,100 µl/g značajno ($p<0,05$) je uticala na smanjenje svetloće (*CIE L**) i povećanje uela crvene boje (*CIE a**). Dodatak SEO u koncentracijama od 0,075 i 0,100 µL/g značajno ($p<0,05$) je uticao i na smanjenje oksidacije lipida izražene preko TBARS vrednosti. Svih pet testiranih koncentracija SEO rezultiralo je na značajnu ($p<0,05$) inhibiciju rasta mikroorganizama. Ova studija pokazuje da se etarsko ulje žalfije može koristiti u proizvodnji barenih kobasica od pilećeg mesa u cilju poboljšanja njihove oksidativne i mikrobiološke stabilnosti kao i poboljšanja boje, bez negativnih reperkusija na miris i ukus finalnog proizvoda.

Ključne reči: *etarsko ulje žalfije*, *barena kobasica*, *novi antioksidanti*, *antimikrobna aktivnost*.

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SOLUBILITY CORRELATION OF SABAH GREEN ROBUSTA COFFEE (*COFFEA CANEPHORA*) BEAN EXTRACT IN SUPERCRITICAL CARBON DIOXIDE EXTRACTION

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This research focuses on the solubility correlation of Sabah green Robusta coffee (Coffea canephora) bean extract using supercritical carbon dioxide (SC-CO_2) extraction. Sabah, the largest coffee-growing area in Malaysia, provides a rich source of Robusta beans for this study. Solubility of coffee bean oil was examined across a range of pressures (10 to 30 MPa) and temperatures (40 °C to 80 °C). The highest solubility, 2.681 mg/g CO_2, was observed at 30 MPa and 40 °C while the lowest solubility was obtained at 20 MPa and 80 °C about 0.440 mg/g CO_2. Thus, as the temperature increased to 80 °C, the solubility decreased significantly, highlighting the inverse relationship between temperature and solubility in this system. Higher pressure, particularly at 30 MPa, led to increased solubility due to enhanced density and solvating power of SC-CO_2. The experimental solubility data showed a great correlation Chrastil's equation, achieving a percentage error about 3.37% compared with del Valle-Aguilera's equation about 14.57%. These results suggest the Chrastil model's suitability for accurately predicting the solubility of green coffee bean oil in SC-CO_2. The study underscores the potential of SC-CO_2 extraction for use in the food industry as an environmentally friendly, solvent-free method to obtain high-quality extracts from coffee beans. This extraction technique can be extended to other bioactive compounds in food processing, offering a sustainable alternative for industrial applications.
Key words: *supercritical carbon dioxide extraction, green robusta coffee bean, solubility, correlation.*

PHYTOCHEMICALS AND ANTIOXIDANT ACTIVITIES OF SARAWAK BARIO RICE VARIETIES

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Rice is a staple diet for almost half of the world's population, offering a diverse range of varieties with distinct characteristics, including pigmented and non-pigmented types. Phenolic and flavonoid compounds in food are acknowledged for their health-promoting benefits and antioxidant properties. This research explores the total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity through the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of different Bario rice varieties. Bario rice varieties are exotic local crops that originated from Sarawak, Malaysia. The study revealed that pigmented rice varieties (BC, BT, and BMS) exhibited higher TPC than non-pigmented varieties (TQR and BAH). At a concentration of 25 mg/ml, the TPC values for pigmented rice were 8.31 mg GAE/g dry weight (BC), 4.69 mg GAE/g dry weight (BT), and 4.0 mg GAE/g dry weight (BMS), whereas the non-pigmented varieties recorded lower TPC values of 2.48 mg GAE/g dry weight (TQR) and 2.41 mg GAE/ g dry weight (BAH). A similar trend was observed for TFC, with higher values in pigmented rice varieties. At a concentration of 3.5 mg/ml, the BMS variety exhibited the highest TFC at 3.06 mg QE/g. The DPPH radical scavenging assay underscores the strong antioxidant potential of pigmented rice, particularly BC (black pigmented rice) with an inhibition percentage of 59.61% at the concentration of 70 mg/ml. The antioxidant activity was attributed to the presence of rice bran, which is rich in phytochemicals, contributing to a greater antioxidative effect. The study underscored the promising potential of Bario rice varieties, as revealed by their profiles of phytochemicals [A1] [AHBAA2] and antioxidant capacity, suggesting their potential contribution to human health.
***Key words**: antioxidant, bario rice, dpph scavenging assay, total phenolic content, total flavonoid content.*

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APPLICATION OF BIOINDICATORS IN BIOPOLYMER PACKAGING MATERIALS

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Smart food packaging systems incorporate natural pigments as bioindicators, offering real-time food quality monitoring by using pH-sensitive compounds to detect spoilage. Changes in pH, influenced by microbial activity and spoilage, cause visible color changes in these pigments, allowing consumers to effectively assess freshness. Natural plant extracts, such as betalains, carotenoids, and anthocyanins, are commonly used due to their bioactivity and colorimetric response to pH variations. These pigments provide non-toxic, sustainable alternatives for active and smart packaging, offering additional antioxidant and antimicrobial properties. Several strategies extend their applicability under different storage conditions. In addition to encapsulation, the application of natural pigments into biopolymer materials improves their chemical and thermal stability.

Carotenoids, betalains, and anthocyanins exhibit distinct pH-responsive behaviors and have been integrated into films for applications in meat, vegetable oils, and other food products. Carotenoids are less explored as bioindicators in smart films due to their stability in low-acid and neutral conditions, but combining them with other natural pigments can enhance sensitivity. Betalains, with high antioxidant activity and better solubility than anthocyanins, are ideal for food packaging applications, particularly in low-acid or neutral environments, and can help with food quality monitoring. Anthocyanins, known for their strong pH sensitivity and color variations, are widely used in smart packaging to detect meat spoilage by responding to pH changes caused by microbial activity. Curcumin and shikonin have also shown promising applications as freshness indicators and shelf-life extenders in biopolymer films.

Natural pigments, besides being an integral part of smart food packaging systems that monitor food quality, are beneficial for the quality and shelf-life of packed products due to a wide range of antioxidative and antimicrobial efficiency. Challenges still remain, such as improving pigment stability and addressing variability in extract composition. The development of hybrid systems, combining pigments or using advanced biopolymers, shows the potential to overcome these limitations and improve the performance of smart packaging solutions, thereby ensuring food safety, reducing waste and promoting circularity.

***Key words**: biopolymer films, bioindicators, carotenoids, betalains, anthocyanins.*

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PRIMENA BIOINDIKATORA U BIOPOLIMERNIM AMBALAŽNIM FILMOVIMA

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Pametni sistemi (smart systems) za pakovanje hrane uključuju prirodne pigmente kao bioindikatore i obezbeđuju praćenje kvaliteta hrane u realnom vremenu korišćenjem pH osetljivih jedinjenja za detekciju kvara. Promene pH vrednosti, pod uticajem mikrobne aktivnosti i reakcija kvara, izazivaju vidljive promene boje ovih pigmenata, omogućavajući potrošačima da efikasno procene svežinu proizvoda. Prirodni biljni ekstrakti, kao što su betalaini, karotenoidi i antocijanini, se obično koriste zbog bioaktivnosti i kolorimetrijskog odgovora na varijacije pH vrednosti. Ovi pigmenti predstavljaju netoksične, održive komponente aktivnog i smart pakovanja, nudeći dodatna antioksidativna i antimikrobna svojstva. Nekoliko strategija proširuje njihovu primenljivost pri različitim uslovima skladištenja. Pored inkapsulacije, primena prirodnih pigmenata u biopolimernim materijalima poboljšava njihovu hemijsku i termičku stabilnost.
Karotenoidi, betalaini i antocijani daju različite odgovore pri promeni pH i integrišu se u ambalažne biopolimerne filmove za pakovanje mesa, biljnih ulja i drugih prehrambenih proizvoda. Karotenoidi su slabije istraženi kao bioindikatori u biopolimernim filmovima zbog velike stabilnosti u neutralnim uslovima i uslovima niske kiselosti, ali kombinovanje sa drugim prirodnim pigmentima može povećati njihovu osetljivost. Betalaini, sa visokom antioksidativnom aktivnošću i boljom rastvorljivošću od antocijana, idealni su za primenu u ambalažnim materijalima, posebno u neutralnim okruženjima i okruženjima sa niskom kiselošću, zbog čega mogu doprineti u monitoringu kvaliteta hrane. Antocijani, poznati po svojoj jakoj pH osetljivosti i varijacijama boje, široko se koriste u smart ambalaži za otkrivanje kvarenja mesa reagujući na pH promene izazvane mikrobnom aktivnošću. Kurkumin i šikonin su se takođe pokazali kao korisni indikatori svežine upakovanih prehrambenih proizvoda, čime se oblast prirodnih bioindikatora dodatno širi.
Prirodni pigmenti, osim što su sastavni deo pametnih sistema za pakovanje hrane koji prate kvalitet hrane, dodatno pozitivno utiču na kvalitet i rok održivosti upakovanih prehrambenih proizvoda zbog širokog spektra antioksidativne i antimikrobne efikasnosti. Izazovi i dalje ostaju, kao što je poboljšanje stabilnosti pigmenta i rešavanje varijabilnosti u sastavu ekstrakta. Razvoj hibridnih sistema, kombinujući pigmente ili korišćenje naprednih biopolimera, pokazuje potencijal da se prevaziđu ova ograničenja i poboljšaju performanse smart rešenja za pakovanje, čime se obezbeđuje bezbednosti hrane, smanjuje otpad i promoviše cirkularnost.
***Ključne reči**: biopolimerni filmovi, bioindikatori, karotenoidi, betalaini, antocijani.*

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MICROFLUIDICS AND MICROFABRICATION

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During the 1980s, significant technological advancements in science enabled the development of devices on a microscopic scale. These devices are known as micro-electromechanical systems (MEMS). Their primary application was focused on technical systems, while in the 1990s, their use expanded into the fields of chemistry, biology, and biomedicine, opening new opportunities for interdisciplinary research and innovation. Within MEMS technology, the need to utilize fluids in various processes within micro total analysis systems (μTAS) led to the popularization of the field of microfluidics in scientific circles.

Microfluidics is an interdisciplinary field that focuses on the study, manipulation, and control of very small volumes of liquids, ranging from microliters to picoliters, within structures that vary in size from a few micrometers to several millimeters. The technological aspect of this field involves the miniaturization and fabrication of devices containing microstructures such as channels, chambers and tunnels, designed to confine and control fluids.

The main advantages of microfluidic systems include the ability to use minimal amounts of samples and reagents, achieving high precision and sensitivity in processes such as separation or detection, all within a short timeframe. Various methods for the fabrication of microfluidic devices and systems, known as microfabrication, have been developed to meet the needs of this field, as described in detail in this paper.

The methodology for creating microchannels directly affects their applicability and compatibility with different media. Fabrication methods are categorized based on the mechanical properties of materials, particularly rigidity, into hard, plastic and soft materials. Material rigidity directly influences the size and resolution of the structures that can be fabricated. Hard materials commonly used in fabrication include glass and silicon. Plastic materials include poly(methyl methacrylate), cyclic olefin copolymer and others, while the most frequently used soft material in fabrication processes is polydimethylsiloxane (PDMS).

The choice of fabrication method depends on the specific application requirements, including temperature conditions (hot or cold environments), chemical reactivity, and biocompatibility. Commonly used techniques include photolithography and its variations, etching, PDMS casting, micromilling, 3D printing and paper-based microfluidics. Paper-based microfluidics, being a biocompatible method, is widely applied in medicine.

Contemporary research is focused on understanding flow-related phenomena and developing more efficient geometric configurations for specific fluids. Interactions between fluids and the materials used in microfluidic chips significantly dictate their applications. As knowledge in the field of microfluidics expands, the development of fabrication methods, as well as their inevitable commercialization and industrialization, is expected. The advancement of microfabrication techniques will lead to simpler, more cost-effective, precise, and faster manufacturing.

Keywords*: microfabrication, microfluidics, MEMS, PDMS.*

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MIKROFLUIDIKA I MIKROFABRIKACIJA

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Tokom osamdesetih godina 20. veka, značajan tehnološki napredak u nauci omogućio je razvoj uređaja na mikroskopskoj skali. Ovi uređaji su poznati pod nazivom mikro elektro mehanički sistemi (MEMS). Njihova primarna upotreba bila je usmerena na tehničke sisteme, dok je tokom devedesetih godina došlo do razvoja njihove primene u oblasti hemije, biologije i biomedicine, čime su otvorene nove mogućnosti za interdisciplinarna istraživanja i inovacije. U sklopu MEMS tehnologije, potreba za korišćenjem fluida u različitim procesima unutar mikrosistema za totalnu analizu (μTAS) dovela je do popularizacije oblasti mikrofluidike u naučnim krugovima.

Mikrofluidika predstavlja interdisciplinarnu oblast koja se bavi proučavanjem, manipulacijom i kontrolom vrlo malih količina tečnosti, u rasponu od mikrolitara do pikolitara, unutar struktura čije dimenzije variraju od nekoliko mikrometara do nekoliko milimetara. Tehnološki aspekt ove oblasti uključuje tehnike minijaturizacije i proizvodnje uređaja koji sadrže mikrostrukture poput kanala, komora i tunela, osmišljenih za ograničenje i kontrolu fluida.

Glavne prednosti mikrofluidnih sistema su mogućnost korišćenja minimalnih količina uzoraka i reagensa, uz visoku preciznost i osetljivost u procesima kao što su separacija ili detekcija, a sve to u kratkom vremenskom okviru. Različite metode za proizvodnju mikrofluidnih uređaja i sistema, poznate kao mikrofabrikacija, razvijene su kako bi zadovoljile potrebe ove oblasti, što je detaljno opisano u ovom radu.

Metodologija izrade mikrokanala direktno utiče na mogućnost njihove primene, kao i upotrebe različitih medijuma. Podela metoda fabrikacije izvršena je na osnovu mehaničkih svojstava materijala, prema krutosti, na tvrde, plastične i meke. Krutost materijala direktno utiče na veličinu i rezoluciju struktura koje se mogu izraditi. Tvrdi materijali koji se najčešće primenjuju u procesu fabrikacije su staklo i silikon. Plastični materijali koji se koriste u procesu fabrikacije su poli(metil metakrilart), ciklični olefinski kopolimer, i drugi, dok se od mekih materijala u procesima fabrikacije najviše primenjuje polimetilsiloksan (PDMS). Izbor metode proizvodnje zavisi od zahteva specifične primene, uključujući temperaturne uslove (topla ili hladna sredina), hemijsku reaktivnost i biokompatibilnost. Najčešće korišćene tehnike uključuju fotolitografiju i njene varijacije, graviranje, livenje PDMS-a, mikroglodanje, 3D štampanje i papirnu mikrofluidiku. Papirna mikrofluidika, kao biokompatibilna metoda, ima široku primenu u medicini. Savremena istraživanja usmerena su na razumevanje fenomena vezanih za strujanje fluida, kao i na razvoj efikasnijih geometrijskih konfiguracija. Interakcije između fluida i materijala od kojih su izrađeni mikrofluidni čipovi diktira njihovu primenu. Sa širenjem znanja iz oblasti mikrofluidike očekivan je i razvoj metoda fabrikacije kao i njihova neminovna komercijalizacija i industrijalizacija. Usavršavanje mikrofabrikacionih metoda dovešće do jednostavnije, jeftinije, preciznije i brže izrade.

***Ključne reči**: mikrofabrikacija, mikrofluidika, MEMS, PDMS.*

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CLIMATE CHANGE IMPACTS ON SEED PRODUCTION AND QUALITY OF PEPPER

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Pepper (*Capsicum annuum* L.) as a commercial species is cultivated worldwide. Abiotic and biotic factors have a considerable effect on plant performance, fruit quantity, and quality. The impact of climate change affects not only the total fruit yield, but also the germination of seeds and the establishment of production in the following year. The quality of the seed, including seed mass, moisture and health, is an important prerequisite for obtaining a healthy and high-quality crop and ensuring high fruit yields. Seed testing of two pepper genotypes from two locations (Smederevska Palanka and Kula) was performed using standard methods for assessing seed quality and health, based on germination parameters, mass of 1000 seeds, moisture and seed health for the seed produced in the season 2024. Germination energy of Romana (Kula) was 50% and 67% (Smederevska Palanka). While, energy germination for Palanačko čudo (Kula) was 55% and 70% (Smederevska Palanka), respectively. Germination energy was statistically significantly lower in locality Kula compared to Smederevska Palanka ($p<0.05$). Total germination for Romana and Palanačko čudo was 70% and 84% in Smederevska Palanka, while in Kula was 66% and 74%, respectively. The moisture content was 8,043% and 6,5% for Romana and Palanačko čudo, respectively ($p<0.05$) in Smederevska Palanka. The moisture content was 7,0% and 10,3 % for Romana and Palanačko čudo in Kula, respectively. Seed health was tested on the basis of the presence of phytopathogenic fungi belonging to the genus *Alternaria* and *Fusarium*. The percentage of infection with *Alternaria* spp. was 1% for Romana and 3% Palanačko čudo in Smederevska Palanka ($p<0.05$), while in Kula amounted to 1% and 4%, respectively ($p<0.05$) and they were statistically significant ($p<0.05$) for Palanačko čudo. There was no statistical difference between detection of Alternaria spp in the Romana variety on both sites. The infection with *Fusarium* spp. was 4.1% for and 1.6% for Palanačko čudo in Kula. The obtained data of seed quality parameters indicate a statistically significant difference between Smederevska Palanka and Kula variety. Future research will focus on the use of biostimulants to increase germination and yield, especially in the Kula locality.
***Key words**: energy, germination, seed health, moisture.*

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UTICAJ KLIMATSKIH PROMENA NA PROIZVODNJU SEMENA I KVALITETA PAPRIKE

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Paprika (*Capsicum annuum* L.) kao komercijalna vrsta se gaji širom sveta. Abiotički i biotički faktori imaju značajan uticaj na performanse biljaka, količinu i kvalitet plodova. Uticaj klimatskih promena utiče ne samo na ukupan prinos voća, već i na klijanje semena i uspostavljanje proizvodnje u narednoj godini. Kvalitet semena, uključujući semensku masu, vlažnost i zdravlje, važan je preduslov za dobijanje zdravog i kvalitetnog roda i obezbeđivanje visokih prinosa plodova. Ispitivanje semena dva genotipa paprike sa dve lokacije (Smederevska Palanka i Kula) obavljeno je standardnim metodama za procenu kvaliteta i zdravlja semena, na osnovu parametara klijavosti, mase 1000 semena, vlage i zdravlja semena za seme proizvedeno u sezoni 2024. godine. Energija klijanja Romane (Kula) bila je 50% i 67% (Smederevska Palanka). Dok je energetska klijavost za Palanačko čudo (Kula) bila 55% i 70% (Smederevska Palanka), respektivno. Energija klijanja bila je statistički značajno niža na lokalitetu Kula u odnosu na Smederevsku Palanku ($p<0,05$). Ukupna klijavost za Romanu i Palanačko čudo bila je 70% i 84% u Smederevskoj Palanci, dok je u Kuli bila 66% i 74% respektivno. Sadržaj vlage je bio 8,043% i 6,5% za Romanu i Palanačko čudo, respektivno ($p<0,05$) u Smederevskoj Palanci. Vlažnost je bila 7,0% i 10,3% za Romanu i Palanačko čudo u Kuli, respektivno. Zdravstveno stanje semena je ispitivano na osnovu prisustva fitopatogenih gljiva Alternaria spp. i Fusarium spp. Procenat infekcije sa Alternaria spp. iznosio je 1% za Romanu i 3% Palanačko čudo u Smederevskoj Palanci ($p<0,05$), dok je u Kuli iznosio 1% i 4% respektivno ($p<0,05$) i bili su statistički značajni ($p<0,05$) za Palanačko čudo. Nije bilo statističke razlike između lokaliteta Romana u detekciji Alternaria spp. Infekcija sa Fusarium spp. bio je 4,1% za i 1,6% za Palanačko čudo u Kuli. Dobijeni podaci o parametrima kvaliteta semena ukazuju na statistički značajnu razliku između Smederevske Palanke i Kule. Buduća istraživanja će se fokusirati na upotrebu biostimulansa za povećanje klijavosti i prinosa, posebno na lokalitetu Kula.
***Ključne reči**: energija, klijavost, vlaga, zdravstvena ispravnost*

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ENCAPSULATION OF CANNABIDIOL-RICH HEMP EXTRACT

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Hemp is grown as an agricultural crop, characterized by low content of psychoactive Δ-9 tetrahydrocannabinol (THC, less than 0.3%). Numerous research caused the increase in scientific knowledge regarding hemp composition and health benefits, whereby much attention has been focused on non-psychoactive cannabinoids, especially cannabidiol (CBD) that exert potent anti-inflammatory, and neuro-protective effects. These findings induced an intense growth in utilization of CBD-based nutritional supplements and cosmetics. Recently, supercritical extraction with carbon dioxide (SCO_2) was shown to extract notable amounts of CBD from hemp compared to the conventional extractions. However, CBD possesses demanding physicochemical characteristics, such as sensitivity against light, rapid degradation and poor water solubility. These features make CBD a suitable candidate for encapsulation into advanced delivery systems (DSs).
In the current investigation, SCO_2 extraction was used for the production of CBD-rich hemp extract using inflorescence of *Cannabis sativa* L., Cannabaceae (*var*. Helena). Comprehensive chemical profiling of the obtained hemp extract was achieved by HPLC analysis. Afterwards, hemp extract was encapsulated into nano-sized DSs that were characterized by determination of mean diameter, polydispersity index (PDI) and zeta potential (assessed by photon correlation spectroscopy, PCS), encapsulation efficiency, as well as pH and conductivity of the obtained dispersion of nano-DSs. To test the preliminary physicochemical stability of the obtained nano-DSs, PSC measurements, as well as pH and conductivity measurements were repeated after 1 month of room temperature storage.
CBD content was 13.02 % in the obtained hemp extract. Encapsulation efficiency of CBD in the nano-DSs was quite high and amounted 99.99%. Their size was 243.30±1.77 nm, with low PDI of 0.213±0.016 indicating uniform particle distribution, while zeta-potential was 65.53±2.65 suggesting good kinetic stability. pH value was 4.62, while conductivity was 423 μs/cm. Repeated measurements of size, PDI, zeta potential, pH and conductivity did not change significantly compared to the initial measurements, indicating satisfactory preliminary physico-chemical stability of the developed nano encapsulants of CBD-rich hemp extract.
In conclusion, hemp extract rich in CBD was successfully encapsulated into nano-sized DSs which were proven to enable satisfactory preliminary physico-chemical stability of CBD, otherwise sensitive to environmental conditions. Further investigations of biological activities of the developed nano-vehicles are needed to enable their potential application in the food, cosmetic and pharmaceutical industry.
Key words*: supercritical carbon dioxide extraction, nano-sized delivery systems, preliminary physico-chemical stability.*

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INKAPSULACIJA EKSTRAKTA KONOPLJE OBOGAĆENOG KANABIDIOLOM

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Konoplja se gaji kao poljoprivredna kultura sa niskim sadržajem psihoaktivnog jedinjenja Δ-9 tetrahidrokanabinola (THC, manje od 0,3%). Dosadašnja brojna istraživanja konoplje dovela su do naučnih saznanja u vezi sa njenim sastavom i zdravstvenim prednostima, pri čemu se sve više pažnje usmerava na nepsihoaktivne kanabinoide, posebno kanabidiol (CBD) koji ispoljava snažno antiinflamatorno i neuroprotektivno delovanje. Navedena naučna otkrića dovela su do intenzivnog porasta upotrebe dodataka ishrani i kozmetike na bazi CBD-a. Nedavno je pokazano da natkritična ekstrakcija ugljenik(IV)-oksidom (NKE) može da izdvoji značajnu količinu CBD-a iz konoplje u poređenju sa konvencionalnim ekstrakcijama. Međutim, CBD poseduje nepovoljne fizičko-hemijske karakteristike, kao što su osetljivost na svetlost, brza degradacija i loša rastvorljivost u vodi. Ove karakteristike čine CBD pogodnim kandidatom za inkapsulaciju u napredne sisteme isporuke (SI).
U ovom istraživanju, NKE iz cvasti *Cannabis sativa* L., Cannabaceae (*var*. Helena) je korišćena za proizvodnju ekstrakta konoplje bogatog CBD-om. Sveobuhvatno hemijsko profilisanje dobijenog ekstrakta konoplje postignuto je HPLC analizom. Nakon toga, ekstrakt konoplje je inkapsuliran u SI nano veličine, koje su okarakterisane određivanjem srednjeg prečnika, indeksa polidisperznosti (PDI) i zeta potencijala (procenjenog foton korelacionom spektroskopijom, FKS), određivanjem efikasnosti enkapsulacije, kao i pH i provodljivosti dobijene disperzije nano-SI. Da bi se ispitala preliminarna fizičko-hemijska stabilnost FKS merenja, kao i merenja pH i provodljivosti su ponovljena nakon 1 meseca čuvanja uzoraka na sobnoj temperaturi.
U dobijenom ekstraktu konoplje sadržaj CBD-a bio je 13,02 %. Efikasnost inkapsulacije CBD-a u nano-SI je bila prilično visoka i iznosila je 99,99%. Njihova veličina je bila 243,30±1,77 nm, sa niskim PDI od 0,213±0,016 što je ukazalo na ujednačenu distribuciju čestica, dok je zeta-potencijal bio-65,53±2,65 ističući dobru kinetičku stabilnost. pH vrednost je bila 4,62, dok je provodljivost bila 423 μS/cm. Rezultati ponovljenih merenja veličine čestica, PDI, zeta potencijala, pH i provodljivosti nisu se značajno razlikovala u poređenju sa rezultatima početnih merenja, što je ukazalo na zadovoljavajuću preliminarnu fizičko-hemijsku stabilnost razvijenih nanoinkapsulanata ekstrakta konoplje bogatog CBD-om.
U zaključku, ekstrakt konoplje bogat CBD-om uspešno je inkapsuliran u SI nano veličine za koje je pokazano da obezbeđuju zadovoljavajuću preliminarnu fizičko-hemijsku stabilnost CBD-a, inače osetljivog na ambijentalne uslove. Potrebna su dalja istraživanja bioloških aktivnosti razvijenih nano-SI kako bi se omogućila njihova potencijalna primena u prehrambenoj, kozmetičkoj i farmaceutskoj industriji.
***Ključne reči**: natkritična ekstrakcija ugljen-dioksidom, sistemi za isporuku nano veličine, preliminarna fizičko-hemijska stabilnost.*

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COMPARATIVE CHEMICAL STUDY OF THREE *JUNIPERUS* SPECIES

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Plant-derived products and their compounds have been used in traditional medicine since early times. Recent works report promising potential regarding the use of plants in the treatment and/or prevention of several hard-to-cure diseases, such as atherosclerosis, cancer, cardiovascular diseases, diabetes, and neurological disorders, among others. The genus *Juniperus* has been recognized as the source of valuable active compounds. This genus includes roughly 68 species and 36 varieties and belongs to the Cupressaceae family. This work gave insight into differences in chemical composition and antioxidative properties of three *Juniperus* sp., namely *J. communis* L. (common juniper), *J. oxycedrus* L. (prickly juniper) and *J. sibirica* L. (Siberian juniper). Common juniper (*J. communis* L.), based on the information provided by EMA monograph and PDR, is traditionally used to treat renal suppression, acute and chronic cystitis, bladder catarrh, albuminuria, leucorrhea, and amenorrhea. These uses are mainly attributed to its bioactive compounds belonging to different secondary metabolite groups, such as polyphenols, terpenoids, organic acids, flavonoids, tannins. While the data on common juniper are abundant, the investigations considering the prickly and Siberian juniper are scarce.

The folium and ripe pseudofructus from all three species were collected from a locality in Montenegro (Plav, the mountain Čakor) in August 2019. The extraction method was maceration, performed using 70% EtOH, the plant material was ground until the particle size was 0.7 mm, while the drug:extract ratio was kept to be 1:5. To determine total phenolics, Folin–Ciocalteu (FC) spectrophotometric method was applied, while total procyanidins and tannins were estimated by following the procedure described in 10th European Pharmacopoeia. The antioxidant capacity of extracts was assessed by the DPPH and FRAP assays. The obtained results (Table 1) pointed out the differences between the investigated species. While the TP content was similar in *J. communis* and *J. oxycedrus, J. sibirica* although less abundant in tannin and polyphenolic content, exhibited significant antioxidant properties, comparable to control (BHT).

Table 1. Total polyphenolic (TP), total tannin (TT) and procyanidin content and antioxidant potential of macerates obtained from different plant parts of three investigated *Juniperus* species

Plant species	Plant part	Antioxidant activity		TP (mg GAE/g)	TT (%)	Procyanidins (%)
		DPPH IC_{50} (µg/ml)	FRAP (mmol Fe2+/g)			
J. communis	*Ripe pseudofructus*	98.60	0.17	13.23	1.73	-
	Folium	34.65	0.46	134.22	6.70	4.41
J. oxycedrus	*Ripe pseudofructus*	325.68	0.19	10.84	1.48	1.47
	Folium	28.20	0.02	159.55	3.11	6.24
J. sibirica	*Ripe pseudofructus*	90.80	0.17	15.60	1.53	-
	Folium	29.60	0.66	18.73	0.72	1.74
BHT		20.00	1.71			

Considering the chemical composition and pharmacological properties of the examined *Juniperus sp.* extracts, the results of the current study might represent the base for further investigation of the cytotoxic and safety profile of this species.

Key words: *Juniperus sp., maceration, chemical and antioxidant properties.*

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UPOREDNA ANALIZA HEMIJSKOG PROFILA TRI VRSTE RODA *JUNIPERUS*

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Proizvodi biljnog porekla i njihova jedinjenja koriste se u tradicionalnoj medicini od davnina. Nedavni radovi pokazuju obećavajući potencijal u pogledu upotrebe biljaka u lečenju i/ili prevenciji teško izlečivih bolesti, kao što su ateroskleroza, rak, kardiovaskularne bolesti, dijabetes i neurološki poremećaji, između ostalih. Rod *Juniperus* obuhvata oko 68 vrsta i 36 varijeteta i pripada porodici Cupressaceae i prepoznat je kao izvor vrednih aktivnih jedinjenja. Ovaj rad daje uvid u različitost hemijskog i antioksidantnog profila ekstrakata dobijenih iz tri *Juniperus* vrste, i to *J. communis L.* (obična kleka), *J. oxycedrus* L. (primorska kleka) i *J. sibirica* L. (patuljasta kleka). Obična kleka (*J. communis* L.), na osnovu podataka EMA monografije i PDR, tradicionalno se koristi za lečenje bubrežnih problema, akutnog i hroničnog cistitisa, katara bešike, albuminurije, leukoreje i amenoreje. Ova upotreba se uglavnom pripisuje njegovim bioaktivnim jedinjenjima koja pripadaju različitim grupama sekundarnih metabolita, kao što su polifenoli, terpenoidi, organske kiseline, flavonoidi, tanini. Dok su podaci o običnoj kleki obilni, istraživanja o primorskoj i patuljastoj kleki su oskudna. List i zreli plod sve tri vrste prikupljeni su na lokalitetima u Crnoj Gori (Plav, planina Čakor) u avgustu 2019. Metoda ekstrakcije je bila maceracija, sa 70% EtOH kao ekstragensom, biljni materijal je mleven do veličine čestica 0,7 mm, dok je odnos biljni materijal:ekstrakt bio 1:5. Za određivanje ukupnih fenola primenjena je Folin–Ciocalteu (FC) spektrofotometrijska metoda, dok su ukupni procijanidini i tanini kvantifikovani po postupku opisanom u 10. Evropskoj Farmakopeji. Antioksidativni kapacitet ekstrakata je procenjen DPPH i FRAP testovima. Dobijeni rezultati (**Tabela 1**) ukazali su na razlike između ispitivanih vrsta. Dok je sadržaj TP bio sličan kod *J. communis* i *J. oxycedrus, J. sibirica*, iako manje bogat u sadržaju tanina i polifenola, pokazala je značajna antioksidativna svojstva, uporediva sa kontrolom (BHT).

Tabela 1. Sadržaj ukupnih polifenola (TP), ukupnih tanina (TT) i proantocijanidina i antioksidantni potencijal macerata dobijenih iz listova i zrelih plodova tri ispitivane *Juniperus* vrste

Biljna vrsta	Droga	Antioksidativni potencijal		TP (mg GAE/g)	TT (%)	Procyanidins (%)
		DPPH IC_{50} (µg/ml)	FRAP (mmol Fe2+/g)			
J. communis	*Zreo plod*	98.60	0.17	13.23	1.73	-
	List	34.65	0.46	134.22	6.70	4.41
J. oxycedrus	*Zreo plod*	325.68	0.19	10.84	1.48	1.47
	List	28.20	0.02	159.55	3.11	6.24
J. sibirica	*Zreo plod*	90.80	0.17	15.60	1.53	-
	List	29.60	0.66	18.73	0.72	1.74
BHT		20.00	1.71			

S obzirom na hemijski sastav i farmakološka svojstva ekstrakata ispitivanih *Juniperus* vrsta, rezultati prikazane studije mogu predstavljati osnovu za dalje istraživanje citotoksičnog i bezbednosnog profila ovih vrsta.

***Key words**: Juniperus vrste, maceracija, hemijska karakreiyacija i antioksidativni potencijal.*

Zahvalnica: Ovaj rad je podržalo Ministarstvo nauke, tehnološkog razvoja i inovacija Republike Srbije (ugovor br. 451-03-136/2025-03/200003).

KEY OBSTACLES IN OPTIMIZING BIOGAS PRODUCTION FOR POWERING COMBINED HEAT AND POWER AND FUEL CELL: A CASE STUDY REVIEW

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Optimizing biogas production for powering combined heat and power (CHP) systems and fuel cells, such as Solid Oxide Fuel Cells (SOFCs), presents significant challenges, primarily due to the inherent variability of feedstock, gas composition, system integration, and economic limitations. This study provides an overview of the key obstacles in optimizing biogas production from biomass and proposes effective solutions aimed at improving efficiency, conversion rates, and biogas utilization.
The review reveals that one major challenge in producing biogas from lignocellulosic materials is the rate-limiting hydrolysis step during anaerobic digestion. Additionally, inhibitors and an imbalanced carbon-to-nitrogen (C/N) ratio in the feedstock can significantly hinder digestion. Impurities like carbon dioxide and hydrogen sulfide further degrade biogas quality, necessitating advanced gas upgrading technologies, especially for sensitive fuel cell systems such as SOFCs.
To address these challenges, research underscores the importance of enhancing the hydrolysis stage through pre-treatment methods, catalysts, or co-digestion processes to boost methane yields. Moreover, the integration of hybrid systems combining biogas with other renewable energy technologies, along with government support and ongoing research, offers promising avenues for future efficiency improvements. Continued advancements in gas purification, system design, and maintenance practices will be critical to unlocking the full potential of biogas as a sustainable energy source.
Keywords: *biomass, anaerobic digestion, CHP, fuel cells.*

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VALORIZATION OF NETTLE TEA INDUSTRY BY-PRODUCTS THROUGH INNOVATIVE GREEN EXTRACTION AND FERMENTATION FOR FUNCTIONAL FOOD APPLICATIONS

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Different food industry sectors generate substantial amounts of waste, posing a serious problem if not properly managed. The herbal tea industry by-products that remain after drying and cutting are rich in bioactive compounds such as polyphenols, flavonoids, phenolic acids, etc. however, they are underutilized. Approximately 10–40% (depending on plant species) of the total processed raw material in the herbal filter tea production is by-products in the form of pulvis. The common nettle (*Urtica dioica* L.*)* is an important part of human diet and it is commonly used for treating prostatic hyperplasia, hyperglycemia, allergies, anemia, etc., because of its diverse chemical profile. Since nettle is rich in polyphenols including flavonoids and phenolic acids, vitamins, minerals, etc. it is expected that it can be a good substrate for biotransformation by lactic acid bacteria. The optimized processing, including extraction and biotransformation, can convert these by-products into valuable sources of biologically active compounds for functional food applications. This study compares innovative strategies for the valorization of nettle by-products in accordance to the circular bioeconomy principles. Green techniques, including ultrasound-assisted and non-thermal plasma-assisted extraction were employed for the efficient recovery of bioactive compounds from nettle by-products.

Studied treatments and solvents (water and water/ethanol mixtures) were compared in order to examine their selectivity towards the antioxidant compounds which are suitable substrates for biotransformations. Extracts were used as substrates for the growth of *Ligilactibacillus salivarius* ATCC 11741*,* lactic acid bacteria strain with probiotic potential. Extracts were first lyophilized and later reconstituted with water, to obtain water-based media for *L. salivarius* growth. The antioxidant activity assays, ABTS, DPPH and total phenolic content as well as viability of *L. salivarius* were assessed. Further, biotransformation of aqueous extracts by fermentation with *L. salivarius* was confirmed by HPLC analysis. Fermentation improved the quality of the extract by increasing the concentration of phenolic compounds, namely, caffeic acid (44%), chlorogenic acid (35%) and caffeic acid derivates (44%), while maintaining a high growth rate of tested microorganism. DPPH assay showed high activity of 234 trolox eq/g dm in non-thermal plasma extracted fermented extracts. Although non-thermal plasma is used for its sterilization and antimicrobial properties in some cases, *L. salivarius* showed high viability in both non-thermal plasma and ultrasound treated extracts. The fermentation with *L. salivarius* was directly associated with an increase in the concentration of biologically active compounds, which opens new opportunities for biotransformation of extracts, potentially also with other lactic acid bacteria to obtain new specific fermentation products.

The fermented aqueous extracts showed significant potential as symbiotics with antioxidant and postbiotic properties. The stability of fermented extracts should be further examined in order to propose best route for their exploitation, but increased biological activity suggests that their applications could span from functional food to dietary supplements and cosmetic ingredients.

Key words: *common nettle, non-thermal plasma, ultrasound extraction, Ligilactibacillus salivarius, biotransformation, green extraction.*

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VALORIZACIJA SPOREDNIH PROIZVODA INDUSTRIJE ČAJA KOPRIVE KROZ INOVATIVNU ZELENU EKSTRAKCIJU I FERMENTACIJU ZA PRIMENU U FUNKCIONALHOJ HRANI

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Različiti sektori prehrambene industrije stvaraju značajnu količinu otpada, što predstavlja ozbiljan problem ako se njime ne upravlja na pravi način. Sporedni proizvodi industrije biljnog čaja koji ostaju nakon sušenja i sečenja bogati su bioaktivnim jedinjenjima kao što su polifenoli, flavonoidi, fenolne kiseline itd., međutim, nedovoljno iskorišćeni. Otprilike 10–40% (u zavisnosti od biljne vrste) ukupne prerađene sirovine u proizvodnji biljnog filter čaja su sporedni proizvodi u obliku pulvisa. Kopriva (*Urtica dioica*) je važan deo ljudske ishrane i najčešće se koristi za lečenje hiperplazije prostate, hiperglikemije, alergija, anemije itd., zbog svog raznovrsnog hemijskog profila. Pošto je kopriva bogata polifenolima uključujući flavonoide i fenolne kiseline, vitamine, minerale itd., očekuje se da može biti dobar supstrat za biotransformaciju bakterija mlečne kiseline. Optimizovana prerada, uključujući ekstrakciju i biotransformaciju, može pretvoriti ove nusproizvode u vredne izvore biološki aktivnih jedinjenja za funkcionalnu primenu u hrani. Ova studija upoređuje inovativne metode valorizacije nusproizvoda koprive u skladu sa principima kružne bioekonomije. Zelene tehnike, uključujući ultrazvučnu i ekstrakciju uz pomoć netermalne plazme, korišćene su za efikasan oporavak bioaktivnih jedinjenja iz nusproizvoda koprive.

Upoređeni su i proučavani tretmani i rastvarači (mešavine voda i voda/etanol) kako bi se ispitala njihova selektivnost prema antioksidativnim jedinjenjima koja su pogodni kao supstrati za biotransformacije. Ekstrakti su korišćeni kao supstrati za rast *Ligilactibacillus salivarius ATCC 11741*, soja bakterija mlečne kiseline sa probiotičkim potencijalom. Ekstrakti su liofilizovani i kasnije rekonstituisani vodom, da bi se dobio medijum na bazi vode za rast *L. salivarius*. Procenjivane su antioksidativne aktivnosti, ABTS, DPPH i ukupni fenolni sadržaj, kao i rast *L. salivarius*. Dalje, biotransformacija vodenih ekstrakata fermentacijom sa *L. salivarius* je potvrđena HPLC analizom. Fermentacija je poboljšala kvalitet ekstrakta povećanjem koncentracije fenolnih jedinjenja, i to kofeinske kiseline (44%), hlorogenske kiseline (35%) i derivata kafeinske kiseline (44%), uz održavanje visoke stope rasta ispitivanog mikroorganizma. DPPH test je pokazao visoku aktivnost od 234 trolok ek/g dm u fermentisanim ekstraktima dobijenim primenom netermalne plazme. Iako se netermalna plazma u nekim slučajevima koristi u antimikrobne svrhe*, L. salivarius* je pokazao visoki rast i u ekstraktima dobijenim uz primenu netermalne plazme i u ekstraktima ekstrahovanim uz asistenciju ultrazvukom. Fermentacija sa *L. salivarius* bila je direktno povezana sa povećanjem koncentracije biološki aktivnih jedinjenja, što otvara nove mogućnosti za biotransformaciju ekstrakata, potencijalno i sa drugim bakterijama mlečne kiseline za dobijanje novih specifičnih proizvoda fermentacije.

Fermentisani vodeni ekstrakti su pokazali značajan potencijal kao simbiotici sa antioksidativnim i postbiotičkim svojstvima. Stabilnost fermentisanih ekstrakata treba dalje ispitati kako bi se predložio najbolji put za njihovu eksploataciju, ali povećana biološka aktivnost sugeriše da bi njihova primena mogla da se proteže od funkcionalne hrane do dijetetskih suplemenata i kozmetičkih sastojaka.

Ključne reči: *obična kopriva*, *netermalna plazma*, *ultrazvučna ekstrakcija Ligilactibacillus salivarius*, *biotransformacija*, *zelena ekstrakcija.*

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A NOVEL BIOREFINERY APPROACH FOR FRACTIONATION OF CROP RESIDUES

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Agri-food waste comprises lignocellulosic biomass (LCB), which consists of cellulose, hemicellulose and lignin. This composition makes LCB suitable for producing energy, biofuels, and value-added products within the biorefinery framework. Different pretreatments were developed and widely used to convert lignocellulose into these products. However, many conventional pretreatments are being substituted due to a lack of sustainability, stressing the urge to shift to greener alternatives. This study employed cold plasma as a low-energy technique for corn stalk delignification. Four experimental set-ups were tested for pretreatment – water as a pH-neutral and chemical-free pretreatment, Fenton reagent as acidic, alkaline hydrogen peroxide as an alkaline pretreatment, and natural deep eutectic solvent (NADES) as an emerging green solvent for LCB pretreatment. Each pretreatment was optimised towards achieving the highest delignification rate. Delignified samples were subjected to enzymatic hydrolysis with a commercial mixture of cellulase, hemicellulase and β-glucosidase, *Cellic CTec 2* (Novozymes, Denmark) to estimate the biomass digestibility. Selected samples were tested for biomethane production through anaerobic digestion. The highest delignification was achieved with cold plasma/alkaline pretreatment (79%), followed by cold plasma/NADES (75%), cold plasma/Fenton (56%), and finally cold plasma/water pretreatment (52%). Cold plasma/alkaline and cold plasma/NADES pretreatments also showed potential for increasing biomethane yield. After a 30-day-long anaerobic digestion, samples pretreated with cold plasma/alkaline and cold plasma/NADES pretreatment showed an increase in biomethane production compared to the raw biomass by 9% and 18%, respectively. Moreover, the time needed to achieve 80% of the final biomethane yield (t_{80}) was significantly reduced from 13 days for raw biomass to 5 days for cold plasma/alkaline pretreated, and 7 days for cold plasma/NADES pretreated biomass. At the same time, the lignin fraction was successfully recovered for value-added products while preserving the carbohydrate fraction. Cold plasma proved to be a promising pathway for LCB valorisation following circular economy principles.
***Key words**: corn stalk, delignification, deep eutectic solvents, waste valorisation, anaerobic digestion.*

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NOVI BIORAFINERIJSKI PRISTUP ZA FRAKCIONISANJE ŽETVENIH OSTATAKA

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Otpad iz poljoprivrede i prehrambene industrije predstavlja lignoceluloznu biomasu (LCB), koja se sastoji iz celuloze, hemiceluloze i lignina. Zahvaljujući svom sastavu, LCB je pogodna za proizvodnju energije, biogoriva i proizvoda sa dodatom vrednošću u okviru biorafinerijskih postupaka. Razvijeni su različiti pretretmani koji se koriste za prevođenje lignoceluloze u neki od ovih proizvoda. Međutim, usled nedostatka održivosti, sve više konvencionalnih pretretmana se zamenjuje novim alternativnim metodama, ukazujući na potrebu za prelazak na zelene tehnologije. U ovom radu korišćena je hladna plazma kao niskoenergetska tehnika za delignifikaciju kukuruzne stabljike. Ispitana je mogućnost primene četiri eksperimentalne postavke kao pretretmana – voda kao pH neutralni pretretman bez hemikalija, Fentonov reagens kao kiseli, alkalni rastvor vodonik peroksida kao alkalni pretretman i prirodne duboke eutektičke smeše (NADES, engl. *Natural deep eutectic solvents*), kao nova vrsta zelenih rastvarača koji se mogu koristiti za pretretman LCB. Pretretmani su optimizovani u cilju postizanja najvećeg stepena delignifikacije. Nakon uklanjanja lignina, uzorci su podvrgnuti enzimskoj hidrolizi primenom komercijalne smeše celulaza, hemicelulaza i β-glukozidaza, *Cellic CTec 2* (Novozymes, Danska). Odabrani uzorci su podvrgnuti anaerobnoj digestiji kako bi se ispitala mogućnost proizvodnje biometana. Najveći stepen delignifikacije postignut je primenom kombinovanog plazma/alkalnog pretretmana (79%), zatim plazma/NADES pretretmana (75%), plazma/Fenton pretretmana (56%), i plazma pretretmana u vodi (52%). Nakon 30-dnevne anaerobne digestije, uzorci tretirani kombinovanim plazma/alkalnim i plazma/NADES pretretmanima pokazali su porast prinosa biometana za 9%, odnosno 18%, u odnosu na netretiranu biomasu. Takođe, vreme neophodno za proizvodnju 80% od ukupne količine nastalog biometana (t_{80}) je skraćeno sa 13 dana u slučaju netretirane biomase, na 5 dana za plazma/alkalni, odnosno 7 dana za plazma/NADES pretretman. Istovremeno, ligninska frakcija je razdvojena od ugljenohidratne frakcije i izolovana za dalju upotrebu u biorafinerijskim procesima. Hladna plazma se pokazala kao dobar izbor za valorizaciju LCB u skladu sa principima cirkularne ekonomije.

***Ključne reči**: kukuruzna stabljika, delignifikacija, duboke eutektičke smeše, valorizacija otpada, anaerobna digestija.*

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NATURAL DEEP EUTECTIC SOLVENTS FOR DELIGNIFICATION AND VALORIZATION OF AGRO-INDUSTRIAL WASTE

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Lignocellulosic biorefineries are recognised as a sustainable way to produce a wide range of valuable bio-based products while simultaneously addressing the environmental challenge related to waste disposal and the emission of greenhouse gases. Despite huge advancements in the field of lignocellulosic biorefineries in recent years, the pretreatment of lignocellulose remains a major challenge that limits the implementation of the biorefinery processes at the industrial level. Natural deep eutectic solvents (NADES) have emerged as a promising alternative to traditional treatment technologies based on corrosive acids or alkalis due to the environmentally friendly properties of NADES and their ability to fractionate lignocellulose under relatively mild treatment conditions. In this study, we evaluated the treatment of corncob biomass using NADES based on choline chloride and lactic acid, aiming to achieve efficient biomass delignification and improve the susceptibility of the corncob polysaccharide fraction to enzymatic hydrolysis.
Sun-dried corncob was kindly obtained from a local farm in South Banat, Serbia. The corncob was ground in a hammer mill grinder and a particle fraction between 0.5 mm and 1 mm was collected by sieving and further used in this study. The biomass was treated in a microwave reactor (Monowave™ 300, Anton Paar, Austria) at a constant temperature of 60 °C, 90 °C and 120 °C for 30 min or 60 min, while the molar ratio of choline chloride and lactic acid was 1:1, 1:2, 1:5 and 1:10. After treatment, the solid biomass was separated by filtration, thoroughly washed with distilled water and dried to a constant weight. Treated biomass was analyzed for the lignin content by applying the spectrophotometric acetyl-bromide method. Additionally, the biomass was subjected to enzymatic hydrolysis using commercial cellulase enzymes (Cellic® CTec2, Novozyme, Denmark) and the reducing sugars were determined by the spectrophotometric DNS method.
The results of the present study showed that the highest delignification of corncob can be obtained at temperature of 90 °C and using the NADES based on choline chloride and lactic acid at the molar ratio of 1:10. By treating the biomass for 60 min, delignification of 51.98% was obtained, while shorter treatment also resulted in significant lignin removal, achieving delignification rate of 47.54%. The treatment improved susceptibility of corncob polysaccharide fraction to cellulase enzymes leading to significantly higher yield of reducing sugars in enzymatic hydrolysis, compared with untreated biomass. These fermentable sugars can be further fermented by microorganisms to a variety of bio-based products, including bioethanol and different commodity and platform chemicals. The results obtained in this study indicate that the treatment of corncob using NADES could be attractive option for development of „greener“ and more sustainable biorefinery processes.
***Key words**: biomass treatment, delignification, natural deep eutectic solvents, agro-industrial waste.*

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PRIRODNE EUTEKTIČKE SMEŠE ZA DELIGNIFIKACIJU I VALORIZACIJU AGRO-INDUSTRIJSKOG OTPADA

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Lignocelulozne biorafinerije su prepoznate kao održiv način za dobijanje širokog spektra vrednih bio-proizvoda, dok istovremeno nude rešenje za globalne ekološke izazove koji se odnose na skladištenje otpada i emisiju gasova staklene baste. Uprkos velikom napretku u oblasti lignoceluloznih biorafinerija poslednjih godina, predtretman lignoceluloze i dalje predstavlja veliki izazov koji ograničava primenu ovih procesa na industrijskom nivou. Upotreba prirodnih eutektičkih smeša u tretmanu biomase predstavlja alternativni pristup tradicionalnim tehnologijama koje se zansivaju na upotrebi korozivnih kiselina ili baza zbog ekološki prihvatljivih osobina prirodnih eutektičkih smeša i njihove sposobnosti da frakcionišu lignoceluloznu biomasu pri relativno blagim uslovima tretmana. U ovom radu je ispitivan predtretman kukuruznog oklaska primenom prirodne eutektičke smeše na bazi holin hlorida i mlečne kiseline u cilju postizanja efikasne delignifikacije i poboljšanja enzimske hidrolize tretirane biomase.
Suvi kukuruzni oklasak je dobijen od lokalnog poljoprivrednog gazdinstva u južnom Banatu, Srbija. Za usitnjavanje oklaska je korišćen mlin čekićar, a frakcija veličine čestica u opsegu od 0.5 mm do 1 mm je sakupljena prosejavanjem i dalje korišćena u ovom istraživanju. Biomasa je tretirana u mikrotalasnom reaktoru (Monowave™ 300, Anton Paar, Austrija) pri konstantnoj temperaturi od 60 °C, 90 °C i 120 °C tokom 30 min ili 60 min, dok je odnos molova holin hlorida i mlečne kiseline iznosio 1:1, 1:2, 1:5 i 1:10. Nakon predtretmana, tretirana biomasa je odvojena filtracijom, temeljno isprana destilovanom vodom i osušena do konstantne mase. U uzorcima je određen sadržaj lignina primenom spektrofotometrijske metode sa acetil-bromidom. Takođe, tretirana biomasa je podvrgnuta enzimskoj hidrolizi pomoću komercijalne celulaze (Cellic® CTec2, Novozyme, Denmark), a koncentracija redukujućih šećera je određena primenom spektrofotometrijske DNS metode.
Rezultati ovog istraživanja su pokazali da se najveća delignifikacija kukuruznog oklaska može postići pri temperaturi od 90 °C i upotrebom prirodne eutektičke smeše za čiju sintezu su korišćeni holin hlorid i mlečna kiselina u molarnom odnosu 1:10. Tretmanom biomase u trajanju od 60 minuta je ostvarena delignifikacija od 51,98%, dok je tretman u trajanju od 30 minuta takođe doveo do značajnog smanjenja sadržaja lignina čime je postignuta delignifikacija od 47,54%. Tretman je poboljšao efikasnost enzimske hidrolize kukuruznog oklaska i doveo do značajno većih prinosa redukujućih šećera u poređenju sa netretiranom biomasom. Dobijeni fermentabilni šećeri se mogu dalje koristiti u različitim fermentacionim procesima za proizvodnju bio-proizvoda kao što su bioetanol i biohemikalije. Rezultati dobijeni u ovom radu ukazuju da tretman kukuruznog oklaska pomoću prirodnih eutektičkih smeša može biti atraktivna opcija u razvoju „zelenih“ i održivih biorafinerijskih procesa.
***Ključne reči**: tretman biomase, delignifikacija, prirodne eutektičke smeše, agro-industrijski otpad.*

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OPTIMIZING GREEN PEA DRYING: EFFECTS OF PULSED ELECTRIC FIELD ON DRYING KINETICS AND SUSTAINABILITY

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Green Pea (*Pisum sativum L.*) is the most widespread legume grown worldwide and is one of the ten most important vegetable crops. In 2021, the global harvested area for green peas increased to 8.9 million hectares, with a total production of about 21.4 million tons (FAO). As they are harvested with a high moisture content, drying is essential to extend their shelf-life. Pulsed electric field (PEF) technology, in which short high-voltage pulses are applied between conductive electrodes, disrupts cell membranes, creates pores and improves mass transfer processes and thus drying. In this study, the effects of PEF on the drying kinetics of green peas were investigated. Fresh peas were treated in a chamber with rectangular bipolar pulses (20 µs width, 20 Hz frequency, 1.8 kV/cm electric field strength, 22 kJ/kg specific energy). Both the untreated and PEF-treated peas were dried in a hot air dryer at 40°C, 55°C and 70°C with an air velocity of 2 m/s and a 70% air renewal rate until the moisture content reached 3.5% (w.b.). Six mathematical models were used to describe the drying behavior: Newton, Page, Henderson and Pabis, Logarithmic, Wang and Singh, and Midilli. A life cycle assessment (LCA) according to ISO 14040:2006 and ISO 14044:2006 standards was performed with OpenLCA software and the Ecoinvent database using the ReCiPe 2016 Midpoint (H) method. All mathematical models presented a good fit (R^2: 0.947–1.0). Among which the Midilli model showed the best fit (R^2=0.99-1.0, RMSE=0.005-0.009, SSE=0.001-0.006). The activation energy ranged from 26.25 to 34.37 kJ/mol, with the PEF-treated samples requiring 23.6% more energy to start diffusion. Thermodynamic calculations confirmed an endothermic process, with positive enthalpy values indicating an increased energy requirement after PEF treatment. Negative entropy values decreased with temperature, indicating exothermic transformations and lower molecular heterogeneity. Positive Gibbs free energy values indicated a non-spontaneous process enhanced by PEF and temperature. The results of LCA showed that PEF pre-treatment reduces the overall environmental impact by 14.2%. The PEF treatment significantly improved drying efficiency by reducing drying time by 35.6% and increasing the effective moisture diffusion coefficient by 31.7%. This indicates potential energy savings in large-scale drying. The Midilli model provided the most accurate representation of drying kinetics. These results support the optimization of industrial drying and improve efficiency and sustainability.

Key words: *pulsed electric field, fresh peas, dying kinetic, mathematical modeling, thermodynamics.*

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EXPERIMENTAL IDENTIFICATION OF PELLET´S THERMAL AND THERMO-ENERGETIC PARAMETERS PRODUCED FROM AGRICULTURAL AND FOOD WASTE

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This paper is devoted to the problem of experimental identification of thermal and thermo-energetic parameters of pellets produced on the base of agricultural materials (clover, *Myscanthus*) and agro-food waste (poppy capsules). The paper also presents selected results of thermal analyses of the samples in the context of predicting the energy utilization of agro-food waste. In the methodological part, two standardized transient measurement methods are presented - the plane source and line heat source methods. Both dynamic methods were used as comparative in the investigation of thermal conductivity, thermal diffusivity and volume heat capacity of *Myscanthus* and poppy capsules pellet samples. The analysis of thermal energy parameters – combustion heat and calorific value was carried out on combustion calorimeter IKA C5000. For thermal analyses was used calorimetric system Mettler Toledo TGA/DSC1.
In particular, the dependencies of thermal conductivity and thermal diffusivity on moisture content in the interval (0 – 20) % were investigated. Each point in the experimental graphical dependencies represents the arithmetic average from the 30 separate measurements. Measured samples had different proportions of agricultural material and waste – poppy capsules. Regression equations were obtained by regression analysis. For the dependence of thermal conductivity on moisture content, linear increasing dependencies were identified. In the case of thermal conductivity and volume heat capacity, the graphical dependencies had a non-linear character described by polynomial function of second-degree. All analytical functional dependencies had coefficients of determination in the interval (0.97 – 0.99). The results indicate that as the proportion of poppy capsules in the feedstock increases, the values of the thermophysical parameters also increase. The experimentally obtained values of combustion heat and calorific value for the pellet samples showed an increase in heat of combustion in the interval (18 080 – 19 120) $kJ \cdot kg^{-1}$ and calorific value from 16 930 $kJ \cdot kg^{-1}$ to 17 900 $kJ \cdot kg^{-1}$ with increasing percentage of poppy capsules content. The different properties of pellet samples from the agricultural material and poppy capsules were also confirmed by thermal analysis and were reflected in the different graphical progression of the curves as well as by the shift of the intervals representing the decomposition of material components due to the increasing temperature.
From a practical point of view, the measurement results of thermo-energetic parameters confirmed a significantly positive effect of a higher content of poppy capsules in the feedstock for pellet production on their energetic parameters. It was also confirmed that both biological materials are suitable for pellet production. The results of the research can contribute to the optimization of pellet production conditions in order to achieve an optimal energy balance.
Key words*: thermal conductivity, thermal diffusivity, volume specific heat, agricultural and food waste, thermal analysis.*

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THE PRODUCTION OF TEMPEH

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Tempeh is a traditional fermented food originating from Indonesia. This fermented product has a rich history and a unique production process that sets it apart from other plant-based protein sources. The story of tempeh dates back centuries to Indonesia, where it emerged as a traditional food with deep roots in Javanese culture. Believed to have been discovered accidentally, tempeh's production began with the fermentation of soybeans wrapped in leaves, like banana, teak, or waru leaves by naturally occurring *Rhizopus spp*. mold on a leaf surface. Over time, this fermentation process evolved into a culinary practice that spread across Southeast Asia and eventually reached the global stage. Within Indonesia, tempeh has historically been consumed as an affordable staple source of protein, especially on the islands of Java and Bali. It is consumed in many forms including fried, boiled, steamed, or grilled tempe benguk (made of tofu residue), tempe bongkrek (made of coconut oil or milk press cake), or tempe lamtoro (made of *Leucaena leucocephala* seeds). The fermentation process involves the introduction of the fungus *Rhizopus oligosporus* to cooked beans, forming a compact and solid block with a nutty flavour. Additionally, tempeh can be made from other legumes, grains, or a combination of ingredients, offering a variety of flavours and textures. Although not standardized like soybean tempeh, these nonsoy tempehs are referred by mentioning the substrate before the word “tempeh,” for example, pigeon pea tempeh. Tempeh stands out not only for its unique taste and texture but also for its impressive nutritional profile. In Indonesia, tempeh has been considered a “low-class protein” food commodity due to its low price, abundant supply, and accessibility for people, including those who could not afford meat. Recently, there is a global emergence of initiatives to rebrand tempeh as an affordable, sustainable, and healthy plant-based product, thus vegetarian and vegan-friendly. As a plant-based protein source, tempeh also provides a lot of health benefits which are results of its bioactive compounds.
Production of tempeh includes different processes like washing of the beans, soaking, cooking, cooling and drying, mixing and stuffing of the tempeh mass, fermentation, cooling of the tempeh sausage, unwrapping and slicing, soaking in water and salt, frying, seasoning, packaging and storage. There are at least eight traditional variations of how and in which order these main steps are conducted, including some repetitions of the same steps. Variations in tempeh production were found across different locations in Indonesia. Additionally, the fermentation process in tempeh introduces probiotics, contributing to its potential health benefits for gut health. The production of tempeh has evolved over time, and modern methods often involve the use of controlled environments and commercially available starter cultures to ensure consistency in quality and safety.
***Key words**: tempeh, industrial production, fermentation, plant-based protein.*

THE ROLE OF THE CAMELINA OIL IN DOG DIETS

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The pet food sector needs to become more creative, sustainable, and profitable to effectively meet the demands of a growing world population while reducing their negative effects on the environment. The price and accessibility of ingredients, which impact the pet food industry, is one of the main obstacles to sustainable production. Particularly, the pet food sector is going through a significant transition brought on by shifting consumer preferences and technical developments. The industry is changing quickly, with a projected market value of $136 billion in 2022 and a compound annual growth rate (CAGR) of 11.1% from 2023 to 2027, reaching $224 billion. Increased pet ownership, changing consumer tastes, and the increased humanization of pets are the main drivers of this expansion, driving up demand for natural, high-quality ingredients. Given the enormous potential for exploration, R&D specialists in this sector must focus on creating diets that satisfy pet owners' needs. Nutrients essential to animals' health, appropriate physical development, and cognitive function, such as oils and fats, must be included in this formulation. Omega-6, a polyunsaturated fatty acid (PUFA) found in camelina oil, regulates metabolism, supports bone health, promotes the growth of skin and hair, and supports the reproductive system. Omega-9 fatty acids are another benefit of camelina oil. Dogs cannot produce enough Omega-9 if their bodies are deficient in Omega-3 and Omega-6. Usually, n-3-rich elements are needed to create dog meals that have the optimal n-6:n-3 ratio of 5:1 to 10:1. Two oils that are frequently used to increase n-3 inclusion in canine diets are flaxseed oil (with a favorable n-6:n-3 ratio) (Muir and Westcott, 2003). and fish oil because of its high levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (180 mg EPA, 120 mg DHA/1,000 mg of oil) (Brunner et al., 2008). However, the high availability of alpha-linolenic acid (ALA) in flaxseed oil renders it prone to oxidation, making its use in commercial diets challenging, and the large-scale fish oil production needed to fulfill the demands of the expanding pet food business is not environmentally viable over the long term. There is currently no data directly comparing the effects of camelina oil supplementation to the effects of other oils approved for use in pet foods on markers of skin and coat health and inflammation. The inclusion of oil supplements in canine diets is frequently linked to claims of maintenance or support of skin and coat health (Burron et al., 2021). According to the Association of American Feed Control Officials (AAFCO), the recommended levels of fat with a profile of fatty acids for dog growth & reproduction minimum are crude protein—22.5%, crude fat—8.5%, linoleic acid—1.3%, ALA—0.08%, EPA+DHA—0.05%, and the (Linoleic+Arachidonic):(ALA+EPA+DHA) acid ratio is recommended to be 30:1.
Key words: *petfood, camelina, oil, diets, dogs.*

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ULOGA ULJA OD KAMELINE U ISHRANI PASA

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Cilj sektora hrane za kućne ljubimce je da postane kreativniji, održiviji i profitabilniji kako bi efikasno odgovorio na zahteve rastuće svetske populacije uz istovremeno smanjenje negativnih uticaja na životnu sredinu. Cena i dostupnost sirovina koja utiče na industriju hrane za kućne ljubimce, jedna je od glavnih prepreka održivoj proizvodnji. Industrija hrane za kućne ljubimce prolazi kroz značajnu tranziciju izazvanu promenom preferencija potrošača i razvojem tehnologija, sa projektovanom tržišnom vrednošću od 136 milijardi dolara u 2022. i kombinovanom godišnjom stopom rasta (CAGR) od 11,1% od 2023. do 2027. godine, dostižući 224 milijarde dolara. Veći broj vlasnika kućnih ljubimaca, promena ukusa potrošača i povećana humanizacija kućnih ljubimaca glavni su pokretači tražnje za prirodnim, visokokvalitetnim sastojcima. S obzirom na ogroman potencijal u oblasti istraživanja, stručnjaci u ovom sektoru moraju da se fokusiraju na kreiranje ishrane koja zadovoljava potrebe ne samo kućnih ljubimaca već i zahteve njihovih vlasnika. Hranljive materije neophodne za zdravlje životinja, odgovarajući fizički razvoj i kognitivne funkcije, kao što su ulja i masti, moraju biti uključene u različite formulacije hrane. Omega-6, polinezasićene masne kiseline (PUFA) koje se nalaze u ulju lanika (*Camelina sativa*), regulišu metabolizam, održavaju zdravlje kostiju, poboljšavaju stanje kože, dlake i reproduktivnog sistema. Omega-9 masne kiseline su još jedna od prednosti ulja lanika. Psi ne mogu da proizvedu dovoljno omega-9 kiselina, ukoliko imaju deficit omega-3 i omega-6 kiselina. Obično su potrebne n-3 kiseline za kreiranje hrane za pse koji doprinose optimalnom odnosu n-6:n-3 od 5:1 do 10:1. Dva ulja koja se često koriste za povećanje sadržaja n-3 kiselina u ishrani pasa su ulje lana (sa povoljnim odnosom n-6:n-3) (Muir i Vestcott, 2003) i riblje ulje zbog visokog nivoa eikozapentaenske kiseline (EPA) i dokozaheksaenske kiseline (DHA) (180 mg DHA, 10 mg DHA) (Brunner et al., 2008). Međutim, visoka dostupnost alfa-linolenske kiseline (ALA) u ulju lana čini ga podložnim oksidaciji, što predstavlja izazov u komercijalnoj ishrani, a proizvodnja ribljeg ulja neophodnog za zahteve rastućeg poslovanja sa hranom za kućne ljubimce nije održiva i značajno utiče na životnu sredinu. Trenutno ne postoje podaci koji direktno upoređuju efekte dodatka ulja od lanika sa efektima drugih ulja odobrenih za upotrebu u hrani za kućne ljubimce i njihov uticaj na zdravlje i upale kože i dlake. Uključivanje ulja u ishranu pasa često je povezano sa tvrdnjama o njihovom uticaju na zdravlje kože i dlake (Burron et al, 2021). Prema podacima Associations of American Feed Control Offices (AAFCO) preporučeni nivoi proteina i masti sa profilom masnih kiselina za minimalni rast i reprodukciju pasa su: sirovi protein - 22,5%, sirova mast - 8,5%, linolna kiselina - 1,3%, ALA - 0,08%, EPA+DHA - 0,05%, a preporučuje se odnos (linolenska kiselina+ arahidonska kiselina): (ALA+EPA+DHA) od 30:1.

***Ključne reči**: petfood, lanik, ulje, ishrana, psi.*

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THE ROLE OF SUSTAINABLE AGRICULTURE IN BIOECONOMY

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The bioeconomy, often referred to as 'biobased economy', encompasses the production of biobased resources and their conversion into food, feed, bioenergy and biobased materials. This concept reduces reliance on fossil fuels, decreases GHG emissions and promotes sustainability. A biobased value chain includes the primary production of biobased resources, their conversion to higher-value goods *via* processing and commercialization on the market (Lewandowski et al., 2018). It consists of sub-sectors such as agriculture, forestry, fishery, food and cellulose and paper production, as well as parts of the chemical, biotechnology and energy industries.
The agricultural sector contributes significantly to the development of the bioeconomy through its economic, social and environmental functions. There are significant differences in the intensity of farming, use of yield-creating resources and the involvement of capital in agricultural production, and the production performance is influenced by the diverse agricultural and climatic conditions, quality of agricultural production space, terrain relief and water regimes in different countries (Nowak et al., 2021).
In a sustainable bioeconomy, the use of biobased resources should be optimized with regard to two main criteria: (1) the demand for high-quality food should be satisfied, (2) the remaining biobased resources should ideally be allocated with regard to the maximal ecological, social and economic benefit. This holistic approach in resource allocation is a major pillar of a sustainable bioeconomy and can serve as a blueprint for sustainable and general resource allocation strategies (Lewandowski et al., 2018). Moreover, the resources produced and used in a biobased economy all contain carbon. Thus, they can replace the fossil resources that contain carbon, i.e. coal, oil and natural gas, but can also contribute to the GHG emission reductions and removals by valorizing the CO_2 content in different segments of the value chain, i.e. from valorization in the primary product (e.g. agri-waste) to carbon capture and storage in different biobased products (e.g. biochar).
To conclude, although the role of agriculture as one of the sectors of the economy decreases with the increasing level of socio-economic development, it remains significant for the bioeconomy sector. The importance of agriculture systems not only from its primary production, but also from the production of biomass standpoint, which is a primary source of renewable energy and biobased products. This sector is also essential from the point of view of macroeconomic indicators such as the level of employment and the created gross value added.
Key words*: bioeconomy, sustainability, agriculture.*

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ULOGA ODRŽIVE POLJOPRIVREDE U BIOGOSPODARSTVU

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Biogospodarstvo obuhvaća proizvodnju bioloških resursa i njihovu pretvorbu u hranu, hranu za životinje, biogoriva i biobazirane materijale. Ovaj koncept smanjuje ovisnost o fosilnim gorivima, smanjuje emisije stakleničkih plinova i promiče održivost. Vrijednosni lanac temeljen na biološkoj sirovini obuhvaća primarnu proizvodnju bioloških resursa, njihovu pretvorbu u proizvode dodane vrijednosti i stavljanje na tržište (Lewandowski et al., 2018). Biogospodarstvo obuhvaća podsektore kao što su poljoprivreda, šumarstvo, ribarstvo, hrana i proizvodnja celuloze i papira, kao i segmente kemijske i biotehnološke industrije te energetike.
Poljoprivredni sektor svojim ekonomskim, društvenim i okolišnim djelovanjem značajno pridonosi razvoju biogospodarstva. Postoje značajne razlike u intenzitetu poljoprivrede, korištenju resursa poput posliježetvenih ostataka i uključivanju kapitala u poljoprivrednu proizvodnju, a na učinak proizvodnje utječu različiti poljoprivredni i klimatski uvjeti, kvaliteta prostora za poljoprivrednu proizvodnju, teren i vodni režimi u različitim zemljama (Nowak i sur., 2021.).
U održivom biogospodarstvu, korištenje bioloških resursa trebalo bi optimizirati s obzirom na dva glavna kriterija: (1) potražnja za visokokvalitetnom hranom trebala bi biti zadovoljena, (2) preostali biološki resursi trebali bi se rasporediti s obzirom na maksimalnu ekološku, društvenu i ekonomsku korist. Ovaj holistički pristup raspodjeli resursa glavni je stup održivog biogospodarstva i može poslužiti kao nacrt za održive i opće strategije raspodjele resursa (Lewandowski i sur., 2018.). Štoviše, svi resursi proizvedeni i korišteni u biološkom gospodarstvu sadrže ugljik. Stoga mogu zamijeniti fosilne resurse koji sadrže ugljik, tj. ugljen, naftu i prirodni plin, ali također mogu doprinijeti smanjenju i uklanjanju emisija stakleničkih plinova valorizacijom sadržaja CO_2 u različitim segmentima lanca vrijednosti, od valorizacije u primarnom proizvodu (npr. posliježetveni ostatak) do hvatanja i skladištenja ugljika u različitim biobaziranim proizvodima (npr. biougljen proizveden procesom pirolize).
Zaključno, iako se uloga poljoprivrede kao jednog od sektora gospodarstva smanjuje s porastom socioekonomskog razvoja, ona ostaje značajna za sektor biogospodarstva. Važnost poljoprivrednih sustava ne samo sa stajališta primarne proizvodnje, već i sa stajališta proizvodnje posliježetvenih ostataka - biomase, koja je primarni izvor u proizvodnji obnovljive energije i bioproizvoda. Ovaj sektor važan je i sa stajališta makroekonomskih pokazatelja poput razine zaposlenosti i stvorene bruto dodane vrijednosti.
***Ključne riječi**: biogospodarstvo, održivost, poljoprivreda.*

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THE ROLE OF SUGAR PLATFORM COMPOUNDS IN THE SUSTAINABLE PROCESSING OF INDUSTRIAL BIO-WASTE

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The management of industrial waste is a fundamental challenge for modern industries, particularly in the context of sustainability and resource efficiency. As global production volumes rise, so does the amount of industrial by-products and waste, necessitating innovative approaches to waste valorisation. The transition from a traditional linear economy to a circular economy (CE) presents an opportunity to mitigate the environmental impact of industrial activities while simultaneously improving resource efficiency. CE is a regenerative economic model that prioritizes waste minimization, resource reuse, and energy efficiency, ensuring that materials and products remain in the value chain for as long as possible. Unlike the linear economy, which follows a "take-make-dispose" pattern, CE integrates closed-loop processes where industrial by-products are transformed into valuable raw materials for further applications.

A key aspect of sustainable bio-waste processing is the utilization of sugar platform compounds—intermediate products derived from biomass hydrolysis, which serve as precursors for biofuels, biochemicals, and bioplastics. These compounds offer a promising solution for waste valorisation across multiple industries. This study explores the application of sugar platform chemistry in three major industrial sectors: the sugar industry, the oilseed processing industry, and the textile industry.

In the sugar industry, large amounts of biomass waste are generated during sugar extraction, primarily in the form of sugar beet pulp and molasses. These by-products, rich in carbohydrates, present an excellent opportunity for conversion into sugar-derived platform chemicals. Through controlled hydrolysis and fermentation, they can be transformed into value-added products such as bioethanol, organic acids, and microbial biomass.

The oilseed processing industry also generates significant waste streams, particularly in the form of rapeseed meal, a by-product of oil extraction. This material, though rich in proteins and fibers, requires further processing to unlock its full potential as a high-value feed ingredient. The proposed method includes an integrated approach involving pre-treatment (hydration and pH correction), enzymatic and acid hydrolysis to reduce fiber content and release fermentable sugars, followed by yeast fermentation to enhance protein content. The final stabilization step ensures product quality and safety, making it a viable alternative protein source in animal feed.

The textile industry, one of the largest global polluters, faces significant challenges in managing textile waste. Synthetic and natural fibers present in textile waste can be hydrolysed to generate fermentable sugars, which can serve as substrates for microbial fermentation or anaerobic digestion, leading to the production of biofuels and biogas. This approach provides a sustainable alternative to traditional disposal methods, reducing landfill accumulation and greenhouse gas emissions.

By leveraging the potential of sugar platform compounds, industries can move toward more sustainable waste management practices, contributing to the circular economy and reducing environmental impact. The integration of biotechnological and chemical processing strategies opens new avenues for industrial symbiosis, where waste from one sector becomes a valuable resource for another. This study highlights the technical and economic feasibility of sugar-based bioconversion pathways, emphasizing their role in the future of sustainable industrial processing.

***Key words**: sugar platform compounds, circular economy, bio-waste valorization, sustainable processing, biomass hydrolysis, biofuels, biochemicals.*

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PRODUCTION OF HIGH-PROTEIN FEED BASED ON BEET PULP AND RAPESEED MEAL

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The increasing demand for sustainable and nutritionally balanced animal feed has led to a growing interest in utilizing industrial by-products. This study presents an innovative approach to the valorization of beet pulp, a by-product of the sugar industry with high energy content due to its digestible pectin, hemicellulose, and cellulose, and rapeseed meal, a residue from the oil extraction process rich in protein and sulfur-containing amino acids. These materials, although widely available, are often underutilized due to their limited nutritional value in their raw form.
To enhance their applicability in animal nutrition, the feedstock was enriched with yeast-derived protein, significantly improving its protein content and digestibility. The process involved controlled mixing, enzymatic treatment, and thermal-mechanical processing, ensuring optimal incorporation of yeast biomass into the raw materials. For instance, sugar beet pulp, which typically contains about 5% crude protein and 23% dry matter, can be transformed into a high-value feed additive with yeast. Rapeseed meal, with a crude protein content of approximately 35%, serves as a cost-effective alternative to soybean meal, although its protein digestibility is lower, therefore, the key issue is to increase the protein content of rapeseed meal so that it can be an alternative to soybean meal.
The final product - a high-protein feed supplement - offers a cost-effective and environmentally friendly alternative to conventional protein sources, such as soybean meal. This approach not only provides an efficient method for managing agro-industrial residues but also aligns with circular economy principles by reducing waste generation and promoting resource efficiency. The developed feed formulation has the potential to support sustainable livestock production while addressing the challenges of protein scarcity in the feed industry. By leveraging these underutilized resources, the feed industry can reduce its reliance on imported soybean meal, contributing to a more sustainable and localized food system.
Key words*: high-protein feed, sugar beet pulp, rapeseed meal, sustainable animal nutrition, circular economy.*

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ENERGY POTENTIAL OF THE SUGAR INDUSTRY IN THE CONTEXT OF USING MOLASSES AS THE MAIN RAW MATERIAL FOR BIOGAS PRODUCTION

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Poland achieved a record sugar production during the 2024/2025 sugar campaign. The sugar beet harvest reached approximately 18.4 million tonnes, resulting in the production of over 2.58 million tonnes of sugar—the highest output in the history of Poland's sugar industry. One of the key by-products of this sector is beet molasses.

Beet molasses is a thick, dark brown syrup with a sweetish taste, formed as a by-product in the final stage of sugar production when further crystallization of sugar is no longer economically viable. It contains approximately 40–55% sugars, primarily sucrose, but also glucose and fructose, along with minerals, proteins, amino acids, organic acids, and polyphenols. These components make it a valuable raw material widely used in various industries.

Molasses is particularly prevalent in the animal feed industry, where it serves as a readily digestible energy source while enhancing feed palatability, especially for cattle. In the fermentation industry, it is used for ethanol, citric acid, and yeast production. In some countries, molasses also finds applications in the food industry as an ingredient in baked goods, energy bars, sauces, and liqueurs. Additionally, it plays a crucial role in the production of organic fertilizers due to its high potassium and trace element content, as well as in biogas plants, where it enhances methane production efficiency. Furthermore, molasses is utilized in cosmetics and plant care.

As a by-product of the sugar industry, beet molasses has significant economic potential despite some limitations. Given that molasses accounts for approximately 3.5–4% of the total weight of processed beets, an estimated 643,000 to 736,000 tonnes of molasses were produced in the 2024/2025 campaign.

The high energy potential of molasses stems primarily from its high simple sugar content, which constitutes about 45–60% of its weight. With an energy value of approximately 232–234 kcal per 100 g, it serves as an efficient substrate for microorganisms in fermentation processes. The availability of fermentable sugars enables an average biogas yield of 0.35 m^3 per kg of molasses. Based on this, the estimated biogas potential from Poland's 2024/2025 molasses production is approximately 235 million m^3. Assuming a methane content of 60%, this would correspond to roughly 140 million m^3 of methane. Given that methane has an energy density of approximately 55.5 MJ/m^3, the estimated energy potential is around 8,000,000 GJ.

The beet molasses produced in Poland during the 2024/2025 campaign represents a significant renewable energy source for biogas production. Its estimated energy potential ranges up to 8 TWh, depending on the quantity of molasses produced and fermentation efficiency. Utilizing this resource could contribute to increasing the share of biomass energy in Poland's national energy mix.

***Key words**: beet molasses, sugar industry, biogas production, renewable energy, fermentation, methane yield, biomass energy, energy potential.*

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USE OF DEFECATION LIME FROM SUGAR PRODUCTION AS FERTILIZER IN SUSTAINABLE SUGAR FACTORY MANAGEMENT

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Poland achieved a record sugar production during the 2024/2025 sugar campaign. The sugar beet harvest reached approximately 18.4 million tonnes, resulting in the production of over 2.58 million tonnes of sugar—the highest output in the history of Poland's sugar industry. One of the key waste products from the sugar industry is defecation lime. Defecation lime is a by-product produced during the processing of sugar beets in sugar factories. It is a valuable calcium fertilizer that plays an important role in agriculture, contributing to the improvement of soil quality.

Defecation lime is produced during the defecation stage of beet juice. Defecation is a juice purification process in which calcium hydroxide ($Ca(OH)_2$) is introduced in the form of milk of lime or calcium oxide (CaO) in a dry process. The reaction of these substances with the diffusion juice leads to the precipitation of undesirable substances, such as proteins and pectins, as well as calcium salts and colored substances [1].

After defecation, the juice is filtered and the precipitated sediments are dewatered on filter presses. In this way, defecation mud is created, which after reaching about 70% of dry matter becomes defecation lime. Defecation lime contains about 30% calcium oxide in the form of calcium carbonate ($CaCO_3$), which makes it a valuable source of calcium for plants14. In addition, it contains about 0.4% nitrogen (N), 1.1% phosphorus (P_2O_5), 0.1% potassium (K_2O), 1.2% magnesium (MgO) and about 12% organic matter. It also contains microelements, which additionally increases its value as a fertilizer. As part of the research, we monitored the elemental composition of lime obtained in the sugar factory in Dobrzelin KGS S.A. in the 2023/2024 campaign. As part of the research conducted as part of the Agrotech (POIR.01.01.01-00-2140) project, a batch of calcium granulate was produced. In addition to its wide use as a fertilizer, defecation lime can also be a component of feed for laying hens. An attempt was made to obtain a feed preparation intended for feeding laying hens based on lime.

Defecation lime is used as a cheap and effective calcium fertilizer. Its main role is to raise the pH of the soil, which is particularly important for plants sensitive to acidification, such as sugar beets, which require a pH between 6 and 7. Liming the soil improves its structure, increases its permeability and facilitates access of oxygen and water to the roots of plants.

***Key words**: defecation lime, sugar beet processing, calcium fertilizer, soil amendment, liming, agricultural by-product.*

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APPLICATION OF BIOINOCULANTS IN THE FUNCTION OF OPTIMIZING AND REDUCING THE USE OF MINERAL FERTILIZERS FOR ACHIEVING A HIGHER YIELD AND QUALITY OF SILAGE MAIZE

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Maize is one of the most important crops, with significant agricultural and economic importance both globally and in Bosnia and Herzegovina. In Bosnia and Herzegovina, approximately 320,000 hectares are sown with cereals, of which 200,000 hectares are maize. Despite being the most important crop, domestic maize production only meets half of the demand, with average yields far below global standards, primarily due to insufficient fertilization. To achieve high yields and quality, it is essential to ensure optimal amounts of nitrogen (N), phosphorus (P), and potassium (K) in the soil. New technologies, such as the use of rhizobacteria like Pseudomonas and Bacillus, can reduce dependence on mineral fertilizers, especially due to phosphorus-deficient soils in Bosnia and Herzegovina. This research aims to improve maize productivity and soil fertility through the use of biological fertilizers and adequate fertilization. Experimental trials are conducted on the fields of KJP "Poljoprivredno dobro Butmir," which annually sows about 200 hectares of silage maize for feeding 400-500 dairy cows. Various fertilization methods are tested to identify the most effective techniques for improving maize production.

Key words: *maize, fertilization, PGP bacteria.*

ARTIFICIAL INTELLIGENCE IN FOOD PROCESSING

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Artificial intelligence (AI) represents the most recent technology introduced into the food industry in recent years, due to the increase in demand for food in line with the increase in world population and the need for efficient production. The ability of these intelligent systems to perform various tasks, such as food quality determination, control instrument management, food classification and production forecasting according to market demands, has intensified the demand for the application of artificial intelligence in the food industry. AI in Food Processing enables interactive and constant control of the entire supply chain process by considering a multi-parametric system: price forecasting, the optimization of production processes, inventory management, the management of logistics are all elements peculiar to the application context of AI in Food Processing. In addition, AI systems intervene in molecular tagging of raw materials and ingredients and help predict demand for efficient transportation program, pricing, and inventory updating, avoiding excess or shortages in product availability. Furthermore, given the high level of failure of new products, the industry is increasingly relying on AI techniques not only to help R&D efforts move faster, but also to find promising ideas much more quickly, often accompanied by "road maps" showing how to turn them into products. One of the most important applications of AI in the food industry to date have been in R&D and marketing, where the power of digital computing and algorithmic connection provides companies in the most innovative sectors with the ability to rapidly change production approaches and come up with countless new ideas for products and sales methods. Object of this speech will be the results of an introduction of the topic of the AI in food processing, with the collection of some case-studies of best practices exemplifying the application of artificial intelligence in food processing.
Key words: *artificial Intelligence, food product development, market demand, process optimization.*

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EXPLORING THE POTENTIAL OF AGRO-INDUSTRIAL LIGNOCELLULOSIC WASTE FOR LACCASE PRODUCTION BY WHITE-ROT FUNGUS AND LACCASE COMPREHENSIVE CHARACTERIZATION

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Agro-industrial waste is commonly discarded or incinerated, leading to significant environmental pollution. However, this waste contains chemical properties that allow for its beneficial reuse. For example, certain waste products can serve as substrates for complex fermentation processes in biotechnology. Utilizing agricultural wastes for laccase production through white-rot fungi is an effective approach to both lower production costs and mitigate environmental pollution. Additionally, laccase-mediated delignification improves the nutritional quality of agro-industrial byproducts, making them valuable as animal feed or soil fertilizers. This study explored the potential of four different agro-industrial lignocellulosic wastes—brewer's spent grain, soybean meal, sunflower meal, and spent coffee grounds—for laccase production by the white-rot fungus *Coriolopsis trogii* 2SMKN. Following the production process, the laccase was concentrated and subjected to comprehensive characterization, including determination of molecular weight, pH and temperature optimum, pH and thermal stability, storage stability, and testing the influence of different cation concentrations on enzyme activity. The results showed that all four substrates supported fungal growth and development, though they differed in their ability to induce the production of laccase. The most effective substrate for laccase production was brewer's spent grain, yielding the highest laccase activity of 47.43 IU/g. In contrast, the lowest laccase activity of 2.28 IU/g was observed with spent coffee grounds. The produced laccase exhibited a molecular weight of approximately 60 kDa, with maximum activity at 70 °C and pH 5.5. It was most stable at 60 °C, retaining 66.24% of its initial activity after 360 min of incubation, while its stability decreased at 80 °C. In terms of pH stability, laccase was most stable at its optimal pH of 5.5, where it retained 55.1% of its initial activity after 120 min. Over a 12-month storage period at -20 °C, laccase stability declined, with only 30.21% of its original activity remaining after one year. Copper ions, in concentration ranging from 0.5 to 5 mM, exhibited an inhibitory effect on laccase activity, while magnesium and calcium ions in the same concentration range slightly stimulated its activity. Accordingly, these results highlight that agro-industrial waste is an excellent substrate for laccase production, offering promising catalytic performance.
***Key words**: agroindustrial waste, laccase production, white rot fungi, laccase characterization.*

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ISTRAŽIVANJE POTENCIJALA AGROINDUSTRIJSKOG LIGNOCELULOZNOG OTPADA ZA PROIZVODNJU LAKAZE GLJIVOM BELE TRULEŽI I SVEOBUHVATNA KARAKTERIZCIJA LAKAZE

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Agroindustrijski otpad se uglavnom odbacuje ili spaljuje, što dovodi do značajnog zagađenja životne sredine. Međutim, ovaj otpad odlikuju hemijska svojstva koja omogućavaju njegovu korisnu ponovnu upotrebu. Na primer, određeni otpadni proizvodi mogu poslužiti kao supstrati za složene procese fermentacije u biotehnologiji. Korišćenje poljoprivrednog otpada za proizvodnju lakaze gljivama bele truleži je efikasan pristup za niže troškove proizvodnje i ublažavanje zagađenja životne sredine. Pored toga, delignifikacija posredovana lakazom poboljšava nutritivni kvalitet agroindustrijskih nusproizvoda, čineći ih vrednim kao stočnu hranu ili đubrivo za zemljište. Ova studija je istraživala potencijal četiri različita agroindustrijska lignocelulozna otpada — otpadnog pivskog ječma, sojine sačme, suncokretove sačme i otpadne kafe — za proizvodnju lakaze gljivom bele truleži *Coriolopsis trogii* 2SMKN. Nakon procesa proizvodnje, lakaza je koncentrovana i podvrgnuta sveobuhvatnoj karakterizaciji, uključujući određivanje molekulske mase, pH i temperaturnog optimuma, pH i termičke stabilnosti, stabilnosti tokom skladištenja i ispitivanje uticaja različitih koncentracija katjona na aktivnost enzima. Rezultati su pokazali da sva četiri supstrata podržavaju rast i razvoj gljive, iako su se razlikovali u svojoj sposobnosti da podstaknu proizvodnju lakaze. Najefikasniji supstrat za proizvodnju lakaze bio je otpadni pivski ječam, koji je indukovao najveću aktivnost lakaze od 47,43 IU/g. Nasuprot tome, najniža aktivnost lakaze od 2,28 IU/g primećena je kod otpadne kafe. Proizvedena lakaza je imala molekulsku masu od približno 60 kDa, sa maksimalnom aktivnošću na 70 °C i pH 5,5. Bila je najstabilnija na 60 °C, zadržavajući 66,24% svoje početne aktivnosti nakon 360 minuta inkubacije, dok je njena stabilnost smanjena na 80 °C. U pogledu pH stabilnosti, lakaza je bila najstabilnija pri svom optimalnom pH od 5,5, gde je zadržala 55,1% svoje početne aktivnosti nakon 120 minuta. Tokom perioda skladištenja od 12 meseci na -20 °C, stabilnost lakaze je opadala, te je samo 30,21% njene početne aktivnosti preostao nakon jedne godine. Joni bakra, u koncentraciji od 0,5 do 5 mM, imali su inhibitorni efekat na aktivnost lakaze, dok su joni magnezijuma i kalcijuma u istom opsegu koncentracija blago stimulisali njenu aktivnost. Shodno tome, ovi rezultati naglašavaju da je agroindustrijski otpad odličan supstrat za proizvodnju lakaza sa obećavajućim katalitičkim performansama.
Ključne reči: *agroindustrijski otpad, proizvodnja lakaze, gljive bele truleži, karakterizacija lakaza*

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HYDRODYNAMIC CAVITATION IN VENTURI CHANNELS WITH DIFFERENT DIVERGENT ANGLES

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Hydrodynamic cavitation occurs in hydraulic systems, where due to flow restriction, velocity locally increases and pressure decreases below the vapor pressure. Due to the complexity of many engineering hydraulic systems, simpler geometries are usually adopted for research of cavitation phenomena, both for experimental work and for development of numerical models to predict the development of cavitation and its effects (e.g. cavitation erosion, cavitation noise) in conjunction with existing Computational Fluid Dynamics (CFD) models to simulate the flow. Venturi channels are often used, the flow cross-section is restricted gradually in the channel as a nozzle with a convergent angle towards the minimum cross-section (throat), beyond which the cross-section gradually increases with a divergent angle. As cavitation number is defined by reference pressure (outlet) and reference velocity (at the throat), the throat cross-section influences the development of cavitation (for a given flow rate). However, divergent angle influences the type of cavitation and its dynamics, irrespective of the cavitation number. In the present work, we investigated the influence the divergent angle of the Venturi channel on cavitation formation and dynamics experimentally, by observing the cavitation phenomena with a high-speed camera. For this purpose, three 3D printed inserts were used in the plexi glass test section of a cavitation tunnel, forming three Venturi channels with three different divergent angles. Cavitation formation and dynamics was then observed with a Photron Fastcam SA-Z high-speed camera filming at 20,000 frames per second. For video (image) analysis we used an in-house Python script, to obtain quantitative insight into cavitation dynamics. We present the quantitative results of vapor projected area (a proxy for vapor volume) over time and cavity length. Cavitation dynamics is evaluated qualitatively as well, attached cavitation and cloud shedding are observed. Attached cavity length decreased with increasing divergent angles, however detached cavitation clouds were larger and travelled further downstream before collapsing. Similarly, the overall cavitation projected area (proxy for cavitation volume) was larger with an increasing divergent angle, which is explained with the point of cloud shedding moving upstream as the divergent angle increased producing larger clouds. We conclude that the divergent angle of the Venturi channel has significant impact on cavitation development, which could have important implications for studies of secondary effects of cavitation such as cavitation erosion.

***Key words**: cavitation, Venturi, high-speed video, cloud shedding, image postprocessing.*

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HIDRODINAMIČNA KAVITACIJA V VENTURIJEVIH KANALIH Z RAZLIČNIMI DIVERGENTNIMI KOTI

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Hidrodinamična kavitacija se pojavlja v hidravličnih sistemih, kjer zaradi zožitve pretočnega prereza lokalno naraste hitrost in tlak pade pod parni tlak. Zaradi kompleksnosti številnih inženirskih hidravličnih sistemov se pri raziskavah pojavov kavitacije običajno uporabljajo enostavnejše geometrije, tako za eksperimentalno delo kot za razvoj numeričnih modelov, ki napovedujejo razvoj kavitacije in njene učinke (npr. kavitacijska erozija, kavitacijski hrup) v povezavi z obstoječimi modeli računalniške dinamike tekočin (CFD) za simulacijo toka. Pogosto se uporabljajo Venturijevi kanali, kjer se pretočni prerez postopoma zmanjšuje, podobno kot pri šobi s konvergentnim kotom proti najmanjšemu prerezu (grlu), nato pa se prerez postopoma povečuje z divergentnim kotom. Ker je kavitacijsko število določeno z referenčnim tlakom (na izstopu) in referenčno hitrostjo (v grlu), prečni prerez grla vpliva na razvoj kavitacije pri danem pretoku. Vendar pa divergentni kot vpliva na tip kavitacije in njeno dinamiko, neodvisno od kavitacijskega števila. V tej študiji smo eksperimentalno preučevali vpliv divergentnega kota Venturijevega kanala na nastanek in dinamiko kavitacije z opazovanjem pojavov kavitacije s pomočjo visokohitrostne kamere. V ta namen smo uporabili tri 3D-natisnjene vložke v preizkusnem odseku iz pleksi stekla v kavitacijskem tunelu, s čimer smo oblikovali tri Venturijeve kanale z različnimi divergentnimi koti. Nastanek in dinamiko kavitacije smo nato opazovali z visokohitrostno kamero Photron Fastcam SA-Z, ki je snemala pri 20.000 sličicah na sekundo. Za analizo videoposnetkov (slik) smo uporabili lastno Python skripto, ki je omogočila kvantitativni vpogled v dinamiko kavitacije. Tako so predstavljeni kvantitativni rezultati projecirane površine pare (ocena volumna pare) skozi čas ter dolžine pritrjene kavitacije. Dinamiko kavitacije smo ocenili tudi kvalitativno – opažanja pritrjene kavitacije in kavitacijskih oblakov. Dolžina pritrjene kavitacije se je s povečevanjem divergentnega kota zmanjševala, vendar so bili odtrgani kavitacijski oblaki večji in so potovali dlje dolvodno, preden so so kolapsirali. Podobno se je celotna projecirana površina kavitacije (ocena volumna kavitacije) povečevala s povečevanjem divergentnega kota, kar pojasnjujemo s premikom točke odcepljanja oblakov gorvodno pri večjih divergentnih kotih, kar je povzročilo nastanek večjih oblakov. Zaključujemo, da ima divergentni kot Venturijevega kanala pomemben vpliv na razvoj kavitacije, kar bi lahko imelo pomembne posledice pri preučevanju sekundarnih učinkov kavitacije, kot je kavitacijska erozija.

***Ključne besede**: kavitacija, Venturi, počasni posnetek, odcepljanje oblakov, poobdelava slik.*

INCORPORATING NEXUS ECOLABELS INTO HOUSEHOLD LEVEL FOOD WASTE MITIGATION STRATEGIES – ENVIRONMENTAL PERSPECTIVES FROM LIFE CYCLE ASSESSMENT

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This study provides a comprehensive evaluation of the economic and environmental impacts of food waste reduction through the implementation of Smart NEXUS Ecolabels. Employing the JRC Food Waste Prevention Calculator, the analysis centers on a optimistic-case scenario wherein household food waste is curtailed by 20%. The results reveal that mitigating food waste at this scale yields substantial benefits, with each ton of food waste prevented equating to the conservation of approximately 78 meals, reduction of 323 kg CO_2 equivalent emissions and an estimated cost savings of 133 euros in production and waste management expenditures. Extrapolating these findings to the EU's aggregate annual food waste, the potential large-scale impact is profound, encompassing 4.6 billion meals saved, 19.1 million metric tons of CO_2 equivalent emissions mitigated, and an estimated economic benefit of 7.85 billion euros. The environmental impact assessment, conducted across 16 midpoint categories, underscores the pivotal role of targeted food waste prevention strategies in curbing pollution, conserving natural resources, and bolstering food security. These findings substantiate the transformative potential of Smart NEXUS Ecolabels in facilitating systemic reform, reinforcing the necessity of embedding food waste reduction measures within broader sustainability frameworks to enhance resource efficiency at scale.

Keywords: *sustainability assessment*, *circular economy*, *life cycle assessment*, *resource efficiency*.

SPARKGREEN PROJECT: GREEN TECHNOLOGIES FOR VALORIZATION OF AGRI-FOOD RESIDUES

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Huge amount of agricultural residues is underutilized, often burned. It is estimated that around 5Gts of agricultural biomass is wasted annually. Lignocellulose is a cheap and abundant natural source of linear polymer cellulose and aromatic polymer lignin. Cellulose, lignin and hemicellulose are intertwined and interlinked within the lignocellulose structure which hinders significantly their valorizations in separate processes. Cellulose and its monomer glucose, can be exploited in various processes, from paper production to valorization towards microcrystaline cellulose or biotransformation into platform chemicals. Glucose from cellulose and hexoses and pentoses from hemicellulose can be used for biotechnological production of bio-based chemicals like organic acids. However, conventional processes for fractionation of lignocellulose substrates with acids or alkali, like the pulp mill process, result in around 55% yield. Remaining lignin is left in aggregated form, as kraft technical lignin which can not be easily depolymerised and is often burned. However, if alternative green methods are used for fractionation of lignocellulosic biomass, it is possible to achieve higher recovery rates and to valorize both lignin and carbohydrate fractions. SparkGREEN is testing green technologies like natural deep eutectic solvents (NADES), cold plasma, enzymes and microorganisms to enable simultaneous recovery of carbohydrates and lignin in less aggregated form, suitable for modifications and higher-value applications, including cosmetics, food packaging etc. Depending on the lignocellulosic substrate, different fractionation routes have shown promise. We studied residues remaining after processing of medicinal herbs (e.g. common nettle) and corn stalks as model substrates.

Cascading process of NADES extraction of herbal residues and subsequent fermentation with lactic acid bacteria enabled increase in content of phenolic acids and flavonoids, with higher stability and maintained antioxidant activity over prolonged storage. These processes were performed under mild conditions, with elevated temperatures used only for NADES preparation. Additionally, this way obtained extracts were fortified with potentially probiotic biomass with high viability over 7 logN. NADES showed promise in delignification of corn stalks while non-thermal technology of cold plasma enabled delignification but also substantial modifications of lignin, including production of oxi-lignin and microlignin spheres, which opens new possibilities for application. These treatments and strategies, including NADES and cold plasma treatment also have shown promise for application in anaerobic digestion, resulting in higher biogas production. It remains to estimate feasibility and profitability of these processes at larger scale, but it is clear that these technologies open opportunities to design new, higher value products on currently wasted resources.

Key words: *lignin, lignocellulose, biorefinery, non-thermal treatments, valorization, crop residues.*

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NUMERICAL AND EXPERIMENTAL DETERMINATION OF WIND TURBINE CHARACTERISTICS

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With the increased demand for adoption of green energy production, wind turbines have emerged as a viable technology to meet these demands. Accurate determination of wind turbine characteristics is crucial for optimizing performance, particularly for improving efficiency. In the past a combination of analytical and empirical methods have been developed and used for design of wind turbine rotors, designed characteristics could then be validated on a model rotor. Nowadays computational fluid dynamics (CFD) approach is used to both design and validate wind turbine rotors. We present both the experimental and the numerical approach to determine model wind turbine characteristics.
Experiments were conducted in the wind experimental facility at the turbomachinery laboratory, using the available wind turbine test bed which allows for measurement of electrical power produced by the wind as well as the oncoming wind velocity from which the wind power is calculated.
Numerical simulations were prepared using ANSYS CFX. 3D model of the wind turbine rotor rotating domain was meshed and placed within a stationary domain (sliding mesh approach). The setup also considered the rotor to be driven by the flow – a rigid body approach was used. Thus, a fully transient simulation was prepared, where the power of the rotor and the rotor angular velocity were simulation output parameters.
Velocity distribution from CFD simulation is presented, with streamlines used to visualize the vortex behind the rotor. Both from the simulation and from experiment, the wind turbine characteristic cp – λ was determined. Overall, we found good agreement between results of numerical simulation and experiment. In both cases maximum power coefficient was obtained at $\lambda = 7.1$, with slightly lower power coefficient values predicted by numerical simulation compared to experiment.
CFD model of a wind turbine rotor was validated, therefore confirming that CFD modelling can be used for prediction of wind turbine characteristics. Different rotor designs could then be analyzed, particularly rotors with different blade geometries.
Key words: *wind*, *turbine*, *characteristic*, *experiment*, *simulation.*

Acknowledgment: This work was supported by the Slovenian Research Agency (ARIS) in the framework of Research Program P2-0196 in Power, Process, and Environmental Engineering.

NUMERIČNA IN EKSPERIMENTALNA DOLOČITEV KARAKTERISTIKE VETRNE TURBINE

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Z naraščajočim povpraševanjem po uporabi zelenih virov energije so vetrne turbine postale uveljavljena tehnologija za izpolnjevanje teh zahtev. Natančna določitev karakteristike vetrnih turbin je ključnega pomena za optimizacijo njihove zmogljivosti, zlasti za izboljšanje učinkovitosti obratovanja. V preteklosti so bile razvite in uporabljene različne analitične in empirične metode za načrtovanje rotorjev vetrnih turbin, pri čemer so bile zasnovane karakteristike preverjene na prototipu rotorja. Danes se za načrtovanje in validacijo rotorjev vetrnih turbin uporablja metoda računalniške dinamike tekočin (CFD). V tej raziskavi predstavljamo tako eksperimentalni kot numerični pristop za določitev karakteristik modelne vetrne turbine.
Eksperimenti so bili izvedeni v eksperimentalnem vetrovnem postrojenju v Laboratoriju za turbinske stroje. Ta omogoča merjenje proizvedene električne moči vetrne turbine ter hitrosti vetra, iz katere se izračuna moč vetra.
Numerične simulacije so bile pripravljene s programom ANSYS CFX. 3D-model rotorskega območja vetrne turbine je bil zamrežen in postavljen v stacionarno domeno (pristop drseče mreže). Pri izdelavi numeričnega modela smo upoštevali, da rotor poganja tok – uporabljen je bil pristop togega telesa. Tako je bila izvedena popolnoma časovno odvisna simulacija, pri kateri sta bila moč rotorja in njegova kotna hitrost izhodna parametra simulacije.
Predstavljena je porazdelitev hitrosti iz CFD-simulacije, pri čemer so bile za vizualizacijo vrtinca za rotorjem uporabljene tokovnice. Tako na podlagi simulacije kot tudi eksperimenta smo določili karakteristiko vetrne turbine $C_p - \lambda$. Ugotovili smo, da je v splošnem dobro ujemanje rezultatov numerične simulacije in eksperimenta. V obeh primerih je bil maksimalni koeficient moči dosežen pri $\lambda = 7{,}1$, pri čemer so vrednosti koeficienta moči napovedane iz numerične simulacije nekoliko nižje v primerjavi z vrednostmi iz eksperimenta.
CFD-model rotorja vetrne turbine je bil uspešno validiran, kar potrjuje, da se CFD simulacije lahko uporabijo za napovedovanje karakteristik vetrnih turbin. Na ta način je mogoče analizirati različne zasnove rotorjev, zlasti rotorje z različnimi geometrijami lopatic.

Ključne besede: *veter*, *turbina*, *karakteristika*, *eksperiment*, *simulacija.*

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SOME ASPECTS OF POSITIONING PHOTO VOLTAIC PANELS IN AGROVOLTAICS APPLICATIONS

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The paper addresses some of the challenges which arise from the contemporary initiatives and efforts to advance in the field of agrivoltaics (Solar and Agriculture Co-Location) applications. Due to the fact that during agrivoltaics applications there is normally a possibility to choose the orientation of photovoltaic panels, a challenge arises: what is their optimum orientation and way of mounting. This paper describes complex methodology employed in the research (literature analysis, photovoltaic installation, one-year measurement of key quantities, data post processing, and analysis). The results received are presented in graphical manner. They tackle basic correlation between the electric power produced in correlation to the orientation of photovoltaic panels, all dependable of the time in the day and period of the year. Based on such results, this paper offers some answers regarding optimal azimuth and tilt angles of photovoltaic panels. The results and discussion may be of help when deciding the position of photovoltaic panels in agrivoltaics applications, but also for small household units in rural environment.

Keywords: *agrivoltaics*, *photovoltaic* (*PV*) *panel*, *position*, *azimuth*, *tilt angle*, *optimization*.

POTENTIAL APPLICATION OF CHITOSAN-BASED BIOPOLYMER COATINGS ON FERMENTED DRY SAUSAGES: VARIOUS APPLICATION TECHNIQUES AND THEIR IMPACT ON PRODUCT QUALITY

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Chitin is the second most abundant organic resource on Earth, found in plants, marine invertebrates, insects, fungal cell walls, and certain microorganisms. Despite its widespread availability, chitin is commercially produced almost exclusively from crustacean shells, primarily due to the large quantities of exoskeleton waste generated by the seafood industry. To evaluate the potential of chitosan-based coatings for fermented sausages, commercially available chitosan derived from crustacean shells was used.

Chitosan-based biopolymer coatings were applied to 2 mm thick slices of fermented dry sausage using two techniques: spraying and immersion. A total of six different treatments were performed, differing in drying conditions after coating application. The spray technique involved three successive applications per side, followed by drying in either a ventilated oven (35°C) or a climate chamber (25°C, 15% relative humidity). The immersion technique consisted of three consecutive dipping and draining cycles, followed by drying under the same conditions. An untreated sample served as a control. To assess the effectiveness of the coatings samples were analysed through instrumental color measurements and sensory evaluation of aroma, taste, and overall acceptability.

Instrumental color analysis showed statistically significant ($P < 0.05$) changes in coated samples compared to the control. Immersion-treated samples had lightness values closer to the control, while spray-treated samples exhibited higher lightness and greater yellow color reduction. Sensory evaluation indicated that all samples, except S_3 (spray technique, drying in a climate chamber), were acceptable, with U_1 (immersion technique, drying in a ventilated oven/10 minutes) showing no significant difference from the control in aroma, taste, and overall acceptability. These findings suggest that chitosan-based coatings have potential for application on fermented dry sausages, with the U_1 immersion technique being the optimal treatment.

Key words: *chitosan, biopolymer coatings, fermented dry sausages, color analysis, sensory evaluation.*

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POTENCIJAL PRIMENE HITOZANSKIH BIOPOLIMERNIH PREMAZA NA FERMENTISANE SUVE KOBASICE: UTICAJ RAZLIČITIH TEHNIKA NANOŠENJA NA KVALITET PROIZVODA

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Hitozan je drugi najzastupljeniji organski resurs na Zemlji, prisutan u biljkama, morskim beskičmenjacima, insektima, ćelijskim zidovima gljiva i određenim mikroorganizmima. Uprkos njegovoj širokoj dostupnosti, komercijalna proizvodnja hitozana gotovo isključivo potiče iz ljuštura rakova, prvenstveno zbog velikih količina egzoskeletnog otpada koji nastaje u industriji morskih plodova. U cilju ispitivanja potencijala hitozanskih premaza za fermentisane suve kobasice, korišćen je komercijalno dostupan hitozan dobijen iz ljuštura rakova.

Na tanko narezane listiće čajne kobasice, debljine 2 mm, nanošeni su hitozanski biopolimerni premazi korišćenjem dve tehnike: sprej tehnike i tehnike uranjanja. Ukupno je sprovedeno šest različitih tretmana, koji su se razlikovali prema uslovima sušenja nakon nanošenja premaza. Sprej tehnika obuhvatala je tri uzastopna nanošenja premaza sa obe strane uzorka, nakon čega je sledilo sušenje u sušnici sa cirkulacijom vazduha (35°C) ili u klima komori (25°C, 15% relativne vlažnosti). Tehnika uranjanja sastojala se od tri uzastopna ciklusa potapanja i ceđenja uzoraka, nakon čega je sledilo sušenje pod istim uslovima. Uzorak bez tretmana služio je kao kontrola. Efikasnost premaza procenjena je instrumentalnim merenjem boje i senzorskom evaluacijom arome, ukusa i ukupne prihvatljivosti.

Instrumentalna analiza boje pokazala je statistički značajne ($P < 0,05$) promene kod premazanih uzoraka u poređenju sa kontrolom. Uzorci tretirani uranjanjem imali su vrednosti svetloće boje bliže kontroli, dok su uzorci tretirani sprej tehnikom pokazali veću svetloću i izraženije smanjenje žute boje. Senzorska evaluacija pokazala je da su svi uzorci, osim S_3 (sprej tehnika, sušenje u klimatskoj komori), bili prihvatljivi, pri čemu U_1 (tehnika uranjanja, sušenje u sušnici sa cirkulacijom vazduha/10 minuta) nije pokazao značajnu razliku u odnosu na kontrolu u pogledu arome, ukusa i ukupne prihvatljivosti. Ovi rezultati sugerišu da hitozanski premazi imaju potencijal za primenu na fermentisanim suvim kobasicama, pri čemu se U_1 tehnika uranjanja pokazala kao optimalan tretman.

***Ključne reči*:** *hitozan, biopolimerni premazi, fermentisane suve kobasice, analiza boje, senzorska evaluacija*

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EXPERIENCE WITH PRODUCTION OF CARBON NANOPARTICLES FROM AGRICULTURAL BIOMASS

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Nanoparticle research has seen a 5-fold increase in the last 15 years. Research covers a wide range of nanoparticle types and applications. Nanoparticles have significant applications in different sectors such as the environment, agriculture, food, biotechnology, biomedical, medicines, etc. A special group of nanoparticles are carbon nanoparticles. Carbon nanoparticles can have different morphologies, which expands the range of applications depending on the application requirements. Carbon nanoparticles can be produced from biomass using various thermal, hydrothermal and chemical-thermal processes. Our research is focused on the use of hydrothermal and thermal processes to obtain nanoparticles from agricultural biomass. The first step in production was biomass milling, followed by hydrothermal carbonization and carbonization in an inert atmosphere. Hydrothermal carbonization was an intermediate process with the aim of obtaining spherical nanoparticles. The biomass used was wheat, corn, soybean, sunflower, walnut and hazelnut. The obtained pellets were suspended in different solids as base fluids. The goal of creating such suspensions is to increase the thermal conductivity of the new nanofluid. The particles obtained in this way were in the size range from 100 to 700 nm. The largest proportion in the mass of particles was those with a diameter of 300 nm. Future research will be focused on reducing the diameter of nanoparticles by applying mechanical and chemical treatments.
***Ključne reči**: nanoparticles, HTC, carbonization, biomass*

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ISKUSTVA U PROIZVODNJI UGLJENIČNIH NANOČESTICA IZ BIOMASE

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Istraživanja nanočestica imaju uvećanje trenda veće od 5 puta u poslednjih 15 godina. Istraživanja iobuhvataju različite vrste nanočestića kao i različitu primenu. Nanoparticles have significant applications in different sectors such as the environment, agriculture, food, biotechnology, biomedical, medicines, etc. Posebna grupa nanočestica su ugljenične nanočestice. Ugljenične nanočestice mogu biti različte morfologije čime se proširuje mogućnost primene u zavisnosti od zahteva aplikacije. Ugljenične nanočestice se mogu proizvesti iz biomase primenom različitih termalnih, hidrotermalnih i hemijsko termalnih procesa. Naša istraživanja uskmerena su ka upotrebi hodrotemalnih i termalnih pročesa u cilju dobijanja naniočestica iz poljoprivredne biomase. Prvi korak u proizvodnji bilo je mlevenje biomase, zatim hidrotemalna karbonizacija i karbonizacija u inertnoj atmosferi. Hidrotemalna karbonizacija je bio međuproces sa ciljem dobijanja sferičnih nanočestica. Korišćen je biomasa pšenice, kukuruza, soje, suncokreta, oraha i lešnika. Dobijene čanosestice su suspendovane u različitim telnostima kao baznim fluidima. Cilj kreiranja ovakvih suspenzija je povećanje topletne provodljivosti novog nanofluida. Čestice dobijene na ovaj način bile su veličina u rasponu od 100 do 700 nm. Najveći udeo u masi čestica bio je onih prečnika 300 nm. Buduća istraživanja biće usmerena na smanjenje prečnika naonočestica primenom mehaničkih i hemijskih tretmana.

Ključne reči: *nanočestice, HTC, karbonizacija, biomasa*

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IMPLEMENTATION OF A MONITORING, REPORTING, AND VERIFICATION SYSTEM FOR GREENHOUSE GAS EMISSIONS IN THE REPUBLIC OF SERBIA

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In the Republic of Serbia, the Law on Climate Change was adopted for the first time in 2021. One of the goals of the Law is to establish a system for monitoring, reporting, and verification (MRV) of greenhouse gas emissions, which is part of aligning domestic legislation in the field of environmental protection with European climate regulations, with one significant difference: in the Republic of Serbia, the implementation of the emissions trading system (ETS) is not anticipated until joining the EU.
With the entry into force of the Rulebook on monitoring and reporting on greenhouse gas emissions on January 5, 2024, all operators whose facilities carry out one or more activities listed in the Regulation on types of activities and greenhouse gases are required to submit a request to the Ministry of Environmental Protection for the issuance of a permit for greenhouse gas emissions and to prepare the necessary technical documentation by July 5, 2024. On the other hand, the Ministry was obligated to issue greenhouse gas emission permits to operators within 4 months of receiving a complete request, based on a positive assessment from the Environmental Protection Agency, so that they could monitor GHG emissions in 2025 and report on GHG emissions at the beginning of 2026.
However, considering that this is a completely new type of obligation for operators, that it was necessary to develop a monitoring plan within the technical documentation, numerous accompanying documents, and written procedures, as well as the fact that the Rulebook itself is very extensive and complex, one-third of the facilities have not managed to obtain a greenhouse gas emission permit even today, 9 months after the deadline. It is encouraging that, according to experience from the EU, it takes about 5 years to establish and successfully operate an MRV system, so it is clear that we face a challenging period in the fight to reduce greenhouse gases and combat climate change.
***Key words**: Climate change, GHG, MRV, ETS*

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PRIMENA SISTEMA ZA MONITORING, IZVEŠTAVANJE I VERIFIKACIJU EMISIJA GASOVA SA EFEKTOM STAKLENE BAŠTE U REPUBLICI SRBIJI

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U Republici Srbiji je 2021. godine po prvi put donet Zakon o klimatskim promenama. Jedan od ciljeva Zakona je uspostavljanje sistema za monitoring, izveštavanje i verifikaciju (MRV) emisija gasova sa efektom staklene bašte, što predstavlja deo usklađivanja domaćeg zakonodavstva u oblasti zaštite životne sredine sa evropskom klimatskom regulativom, uz jednu bitnu razliku, u R. Srbiji se do pridruživanja EU ne predviđa primena sistema trgovine emisijama (ETS).

Stupanjem na snagu Pravilnika o monitoringu i izveštavanju o emisijama gasova sa efektom staklene bašte 5.1.2024. godine, svi operateri u čijim postrojenjima se realizuje jedna ili više aktivnosti navedene u Uredbi o vrstama aktivnosti i gasovima sa efektom staklene bašte, bila su u obavezi da do 5.7.2024. godine Ministarstvu zaštite životne sredine podnesu zahtev za izdavanje dozvole za emisiju gasova sa efektom staklene bašte i izrade potrebnu tehničku dokumentaciju. Sa druge strane, obaveza Ministarstva bila je da u roku od 4 meseca od prijema potpunog zahteva, a na osnovu pozitivne ocene Agencije za zaštitu životne sredine, operaterima izda Dozvole za emisiju gasova sa efektom staklene bašte, kako bi isti tokom 2025. godine vršili monitoring GHG i početkom 2026. izveštavanje o emisijama GHG.

Međutim, imajući u vidu, da je ovo potpuno nova vrsta obaveze za operatere, da je u okviru tehničke dokumentacije bilo potrebno izraditi plan monitoringa, mnogobrojne prateće dokumente i pisane procedure, kao i da je sam Pravilnik veoma obiman i kompleksan, trećina postrojenja nije uspela da dobije dozvolu za emisiju gasova sa efektom staklene bašte ni danas, 9 meseci nakon isteka roka. Ohrabrujuće je to da je prema iskustvu iz EU potrebno oko 5 godina za uspostavljanje i uspešno funkcionisanje MRV sistema, tako da je jasno da je pred nama izazovan period u borbi za smanjenje gasova sa efektom staklene bašte i klimatske promene.

***Ključne reči**: Klimatske promene, GHG, MRV, ETS*

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