



# ZBORNIK APSTRAKATA

## VI NAUČNO-STRUČNI SIMPOZIJUM SA MEĐUNARODNIM UČEŠĆEM **„PIVO, PIVARSKЕ SIROVINE I OPREMA“**

Zrenjanin, Srbija  
25 - 27.10.2023. godine  
[www.simpozijumopivu-zrenjanin.org](http://www.simpozijumopivu-zrenjanin.org)





VI NAUČNO-STRUČNI SIMPOZIJUM SA  
MEĐUNARODNIM UČEŠĆEM  
**„PIVO, PIVARSKÉ SIROVINE I OPREMA“**

6<sup>th</sup> SCIENTIFIC-PROFESSIONAL SYMPOSIUM  
WITH INTERNATIONAL PARTICIPATION  
**"BEER, BREWING RAW MATERIALS AND  
EQUIPMENT"**

**ZBORNİK APSTRAKATA  
BOOK OF ABSTRACTS**

Zrenjanin, Srbija  
25 – 27.10.2023. godine

**IZDAVAČ**  
PUBLISHER

**Institut za ratarstvo i povrtarstvo Novi Sad,**  
Institut od nacionalnog značaja za republiku Srbiju

**Institute of Field and Vegetable Crops Novi Sad,**  
National Institute of the Republic of Serbia

**ADRESA IZDAVAČA**  
PUBLISHER'S ADDRESS

**Maksima Gorkog 30, 21101 Novi Sad, Srbija**

Tel: +381 21 4898 100

Fax: +381 21 4898 131

**ISBN**  
978-86-80417-93-6

**ŠTAMPA**  
PRINT

Školska knjiga NS doo  
Živojina Čuluma 32, Novi Sad, Srbija  
Tel: +381 21 419 107



## VI NAUČNO – STRUČNI SIMPOZIJUM „PIVO, PIVARSKJE SIROVINE I OPREMA“

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Institut od nacionalnog značaja za republiku Srbiju



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# ISPITIVANJE METABOLIZMA JEDINJENJA SUMPORA U PIVARSTVU

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Metabolizam jedinjenja sumpora igra važnu ulogu tokom procesa pivarstva. Kritična jedinjenja sumpora, kao što su vodonik-sulfid, sumpor-dioksid, merkaptani i tioestri, predstavljaju jednu od najtežih stavki koje treba kontrolisati. Prisustvo jedinjenja sumpora utiče na senzorni kvalitet piva, a njegova proizvodnja zavisi od sastava slada i vrste kvasca. Prezentacija govori o akumulaciji jedinjenja sumpora u vezi sa nivoima specifičnih aminokiselina prisutnih u sladu, pošto su aminokiseline koje sadrže sumpor (metionin) kritične za metabolizam sumpornih jedinjenja. Drugo, studija istražuje uticaj sirovine na jedinjenja sumpora, kao što su slad, kvasac, aditivi, itd. Pored toga, ekspresija razlika ključnih gena u dva lager kvasca analizirana je na molekularnom nivou (RNA-sek), razjašnjavajući zašto jedan kvasac proizvodi manje sumpornih jedinjenja od drugog, kao i efekat metionina na metabolizam jedinjenja sumpora u pivarstvu.

# STUDY ON METABOLISM OF SULFUR COMPOUNDS IN BREWINGPROCESS

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Metabolism of sulfur compounds plays an important role during the brewing process. The critical sulfur compounds, such as hydrogen sulfide, sulfur dioxide, mercaptans and thioesters, represent one of the hardest items to be controlled through brewing. The presence of sulfur compounds affects the sensory quality of beer, and its production depends on wort composition and type of yeast strain. This presentation discusses the accumulation of sulfur compounds are related to levels of specific amino acids present in wort, as sulfur-containing amino acids (methionine) are critical for yeast metabolism of sulfur compounds. Secondly, the study investigates the effect of raw material on sulfur compounds, such as the malt, yeast, additive and so on. In addition, the expression differences of key genes in two lager yeasts were analyzed at the molecular level (RNA-seq), clarifying why one yeast produces less sulfur compounds than another yeast, and the effect of methionine on metabolism of sulfur compounds in the brewing process.

# BEZBEDNOST VODE U PIVARSKOJ INDUSTRIJI

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Voda za piće je osnovni izvor ishrane i jedan od najvažnijih preduslova života. Primarni je materijal za čitav niz proizvodnih aktivnosti koje podrazumevaju zaštitu bezbedne i zdrave vode za piće. U industrijski razvijenom svetu, znatan deo raspoložive vode za tehnološke potrebe se tehnološki tretira pre nego što uđe u pogone za preradu hrane. Veće pivare obično dobijaju vodu iz sopstvenih bunara ili izvora. Manje zanatske pivare koriste vodu za piće iz javne vodovodne mreže. Voda iz javne mreže je obično mikrobiološki stabilnija, jer se prethodno tretira u postrojenjima za prečišćavanje vode, uključujući ultrafiltraciju kao novi tretman. Najveći deo vode se troši u tehnološkim procesima gde nastaju otpadne vode, dok se deo koji konzumiramo kao pivo koristi za direktnu pripremu. U tehnološki zastarelim pivarama voda se takođe koristi u otvorenim procesima hlađenja kao rashladna voda. U tom slučaju treba voditi računa da se što manje zagađujućih materija ispušta u životnu sredinu. To se može postići sprečavanjem zagađivanja izvora kroz unapređenje postojeće tehnologije, uvođenje sistema kvaliteta, uvođenje najbolje dostupne tehnologije (BAT), reciklažu (voda, otpadni proizvodi i toplota), ekonomičnost vodom, obrazovanje i obuku, osoblja i tretmana otpadnih voda. S druge strane, integrisanu kontrolu prevencije zagađenja (IPPC) treba uvesti u pojedinačne industrije. Lanac ishrane je veoma moćan potrošač vode i treba ga smatrati takvim. Proizvodnja piva je tradicionalno prepoznata kao industrija bezvodna. Sa visokom industrijskom preradom ova potrošnja je opala, ali sa zanatskim procesima pivarstva je počeo da raste i sličan je originalnim konceptima pivarstva. redavanje se fokusira na A) pitanja bezbednosti vode u pivarstvu i B) pitanja bezbednosti, odnosno patogenih mikroorganizama koji se fekalnim zagađenjem prenose u pijaćoj vodi i mogu izazvati infekcije kod ljudi i nekih životinja. Prisustvo mikroorganizama u vodi se i dalje utvrđuje odabranim klasičnim tehnikama, ali i bržim molekularnim metodama. Mikrobiološki stabilna i bezbedna voda se postiže fizičkim uklanjanjem i hemijskom inaktivacijom mikroorganizama. Metode traženja kritičnih tačaka u protoku vode/piva po HACCP sistemu, uz principe higijene, dobre laboratorijske i proizvodne prakse, pokušavaju da garantuju bezbednost izvorišta vode kako bi se smanjio rizik za potrošače.

**Ključne reči:** voda za piće, metode tretmana, rizici od kontaminacije, bolesti koje se prenose vodom, mikrobiološke metode

# WATER SECURITY AND SAFETY FOR BREWING INDUSTRY

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Drinkable water is a fundamental source of nutrition and one of the most important life preconditions. It is a primary material for an entire range of production activities which entails the protection of safe and healthy drinkable water. In the industrially developed world, the considerable part of available water for technological purposes is technologically treated before it enters food processing plants. Larger breweries typically source their water from their own wells or springs. Smaller craft breweries use drinking water from the public water supply network. Water from the public network is usually more microbiologically stable because it is pre-treated at water treatment plants, including ultrafiltration as a recent treatment. Most of the water is consumed in technological processes where wastewater is generated, while a portion that we consume as beer is used for direct preparation. In technologically outdated breweries, water is also used in open cooling processes as cooling water. In that case, we should take care that as less pollutants as possible are released into environment. This can be achieved by preventing pollution of the source through the improvement of existing technology, introduction of the system of quality, introduction of best available technology (BAT), recycling (water, waste products and heat), economizing with water, education and training of staff and wastewater treatment. On the other hand, integrated pollution prevention control (IPPC) should be introduced into individual industries'. Food chain is a very potent water consumer, and should be considered as such. Beer production is traditionally recognized as water intensive industry. With high industrial processing this consumption went down, however with craft brewing processes started to raise and it is similar to original brewing concepts. This lecture focuses on A) security issues i.e. water patterns in brewing and B) safety issues, i.e. the pathogenic microorganisms which are transmitted in the drinkable water through fecal pollution and can cause infections in humans and some animals. The presence of microorganisms in water is still determined by selected classic techniques, but also by faster molecular methods. Microbiologically stable and safe water is achieved through physical removal and chemical inactivation of microorganisms. The methods of searching for critical points in the water/beer flow by HACCP system, with the principles of good hygiene, laboratory and manufacturing practices tries to guarantee the safety of water sources in order to decrease the risk for consumers.

**Key words:** drinkable water, treatment methods, contamination risks, waterborne disease, microbiological methods

# STANJE I INOVACIJE U PROIZVODNJI HMELJA U SLOVENIJI

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Gajenje hmelja u Sloveniji je tradicija više od 100 godina. Počelo je sa uvoznim stranim sortama hmelja u okolini Žalca. Posle Drugog svetskog rata površina hmelja bila je oko 4000 ha. Danas se hmelj gaji na površini od 1600 ha, dajući cca. 2500 t suvog hmelja godišnje, što Sloveniju svrstava na peto mesto na listi svetskih proizvođača hmelja. Sav slovenački hmelj se proizvodi unutar zaštićene geografske oznake od 2017. godine, a 95% proizvedenog hmelja izvozi se širom sveta. Zahtevi globalnog tržišta, razvoj zanatskog pivarskog sektora i klimatske promene zahtevaju adekvatan odgovor u istraživanju hmelja. Slovenija stoga ima intenzivne programe oplemenjivanja hmelja koji su rezultirali 11 novih sorti u poslednjih 10 godina. Nove sorte pokazuju bolju toleranciju na sušu, bolju toleranciju na prosečnu temperaturu i otpornost na bolesti. Polovina novih sorti pripada grupi aromatičnih sorti, koje karakterišu posebne aromatične note pored tradicionalne arome hmelja koja se opisuje kao cvetna, citrusna, voćna ili začinska. Na predavanju će biti predstavljene neke od novih sorti. U prezentaciji će biti reči i o aktuelnim trendovima u agrotehnologiji proizvodnje hmelja, vezanim za smanjenje upotrebe đubriva, pesticida i upravljanja vodama u okviru održivosti u poljoprivredi.

**Ključne reči:** Slovenija, sorte hmelja, program oplemenjivanja hmelja, nove sorte, agrotehnologija



# SITUATION AND INOVATIONS IN HOP PRODUCTION IN SLOVENIA

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Modern hop growing in Slovenia has been a tradition for more than 100 years. It started with the imported foreign hop varieties in the surrounding area of Žalec. After World War II, the hop growing area was about 4000 ha in size. Today hop is grown at an area of 1600 ha, giving appr. 2500 t of dry hops annually, which ranks Slovenia fifth on the list of global hop producers. All Slovenian hops are produced inside the protected geographical designation since 2017 and 95% of the produced hops are exported all over the world. Requirements of the global market, development of the craft brewing sector and climate change demand an adequate response in hop research. Slovenia therefore has intense hop breeding programmes that resulted in 11 new varieties in last 10 years. The new varieties exhibit better drought tolerance, higher average temperature tolerance and disease resistance. Half of the new varieties belong to the group of flavour varieties, characterised by special aromatic notes in addition to the traditional hop aroma which is described as flowery, citrusy, fruity or spicy. Some of the new varieties will be presented in the lecture. Actual trends in agro-technology of hop production, connected with the reduction of the use of fertilizers, pesticides and water management in the frame of sustainability in agriculture, will also be discussed in the presentation.

**Key words:** Slovenia, hop varieties, hop breeding programme, new varieties, agrotechnology

**Acknowledgement:** Paper is a part of the permanent task Technology of hop production financed by the Ministry of agriculture, forestry and food and by hop growers of Slovenia

# CENTAR ZA RAZVOJ, DEMONSTRACIJU I OBUKU ZA TEHNOLOGIJE BEZ UGLJENIKA I POTENCIJAL ZA DEKARBONIZACIJU I KORIŠĆENJE VODONIKA U SEKTORU PIVARA

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Potražnja za hranom i njena potrošnja energije po jedinici proizvodnje značajno su porasli u poslednjih nekoliko decenija<sup>1</sup>. Procene sugerišu da je za svaki 1 J konzumiranog prehrambenog proizvoda potrebno oko 10 J za njegovu proizvodnju i isporuku<sup>2</sup>. Očekuje se da će se potrebe za proizvodnjom hrane povećati do 50% do 2030. godine<sup>3</sup> s obzirom na klimatske promene i rast globalne populacije, čineći dekarbonizaciju izuzetno važnom komponentom održivih prehrambenih sistema. Među potrošnjom hrane i pića, proizvodnja piva proizvodi relativno nizak nivo od 0,6 kg CO<sub>2</sub> po evru, u poređenju sa proizvodima životinjske hrane (u rasponu od 1-3 kg CO<sub>2</sub> po evru)<sup>4</sup>. Zbog toga nekoliko kompanija za proizvodnju piva i slada pokušava proizvodnju piva sa izuzetno malim emisijama CO<sub>2</sub>. Ovde su tipične mere dekarbonizacije usmerene na (i) kruženje toplote, (ii) elektrifikaciju toplote, (iii) smanjenje vode i (iii) anaerobnu digestiju.

Naš pregled će predstaviti opcije za napredna rešenja za dekarbonizaciju, i to:

- Na licu mesta (zelena) proizvodnja vodonika.
- Sagorevanje vodonika kao goriva za proizvodnju pare i/ili električne energije.
- Ekstrakcija bioaktivnih jedinjenja i funkcionalnih materijala.
- Proizvodnja biovodonika.

Pomoćni objekti usmereni su na zelenu proizvodnju vodonika, transformaciju vodonika i ugljen-dioksida u gasovite i tečne proizvode, apsorpciju ugljenika i apsorpciju ugljen-dioksida, kao i na karakterizaciju biomase i nanomaterijala u okviru jedinstvenog Centra za razvoj, demonstraciju i obuku.

**Ključne reči:** dekarbonizacija, vodonik, biovodonik, toplota, elektrifikacija

# CENTER FOR DEVELOPMENT, DEMONSTRATION AND TRAINING FOR CARBON-FREE TECHNOLOGIES AND THE POTENTIAL FOR DECARBONISATION AND HYDROGEN UTILIZATION IN THE BREWERY SECTOR

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Demand for food and its energy consumption per unit of production has grown significantly over the past few decades<sup>1</sup>. Estimates suggest that for every 1 J consumed food product, about 10 J is required for its production and delivery<sup>2</sup>. Food production needs are expected to increase by up to 50 % by 2030<sup>3</sup> considering climate change and growth of global population, making decarbonisation an immensely important component of sustainable food systems. Amongst food and beverage consumption, beer brewing provides a relatively low carbon intensity at 0.6 kg CO<sub>2</sub> per Euro, when compared to animal food products (ranging at 1-3 kg CO<sub>2</sub> per Euro)<sup>4</sup>. Therefore, beer production providing extremely low carbon footprints is being attempted by several brewing and malting companies. Here, typical decarbonisation measures are targeted to (i) heat cycling, (ii) heat electrification, (iii) water reduction and (iii) anaerobic digestion.

Our outline will present options for advanced decarbonisation solutions, namely:

- On site (green) hydrogen production.
- Hydrogen combustion as fuel or for steam and/or electricity production.
- Bioactive compounds and functional materials extraction.
- Bio-hydrogen generation.

The supporting facilities targeted to green hydrogen production, hydrogen and carbon dioxide transformation to gaseous and liquid products, carbon capture through carbon dioxide absorption and absorption, as well as biomass and nanomaterial characterisation within the unique up and coming Center for Development, Demonstration and Training for Carbon-Free Technologies will also be presented.

**Key words:** decarbonisation, hydrogen, biohydrogen, carbon capture, heat, electrification

<sup>1</sup> Renew Sust Energ Rev 143, 2021, 110856

<sup>2</sup> Handbook of Waste Management and Co-Product Recovery in Food Processing 2007, p. 59-89

<sup>3</sup> Proc Inst Civ Eng Energ, 167, 2014, p. 162-170

<sup>4</sup> Energ Effic, 7, 2014, p. 791-810



## PIVSKI TROP - SIROVINA ILI OTPAD?

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Iako je otpadna voda količinski najzastupljeniji nusprodukt u proizvodnji piva, trop je, uz iskorišteni kvasac, svakako najvrjedniji iz mnogih razloga. To je lignocelulozni materijal koji se sastoji od oko 17% celuloze, 28% neceluloznih polisaharida, pretežno arabinoksilana i oko 28% lignina. Zbog visokog sadržaja proteina (oko 20% na suhu tvar) i vlakana (oko 70% na suhu tvar), ali i fenolnih spojeva te nekih minerala, vrlo je atraktivan i nutritivno vrijedan dodatak ljudskoj prehrani. U praksi se prvenstveno koristi kao visokovrijedna hrana za životinje, ali može služiti i za proizvodnju bioplina, može se koristiti u biotehnološkoj proizvodnji (kao supstrat za uzgoj mikroorganizama, u proizvodnji mliječne kiseline, karotenoida, enzima, biogoriva, farmaceutika, komposta, kao nosač za imobilizaciju biokatalizatora), ima potencijalnu primjenu kao biosorbens za uklanjanje onečišćujućih tvari iz vode, može se koristiti za proizvodnju ambalažnih materijala i dr. Procjenjuje se da godišnje u Europskoj uniji nastane više od 3,4 milijuna tona pivskog tropa koji se danas primarno koristi za ishranu stoke te na taj način posredno doprinosi povećanju razine stakleničkih plinova u atmosferi. Ta iznimno vrijedna i vrlo jeftina sirovina ima znanstveno dokazani i iznimno veliki potencijal da bude puno više od puke hrane za životinje. Uz razvoj tehnologije, povećanje cijena energenata i općenito višu svijest o brizi za okoliš te posljedično recikliranje otpada, pivski trop je sirovina koja već u bliskoj budućnosti može biti i vrlo profitabilna i vrlo korisna na puno načina.

# BREWER'S SPENT GRAINS - RAW MATERIAL OR WASTE?

Goran Šarić<sup>1</sup>, Lara Kramarić<sup>1\*</sup>, Natalija Velić<sup>2</sup>

Although waste water is quantitatively most represented by-product in beer production, the spent grains, along with the used yeast, is certainly the most valuable for many reasons. It is a lignocellulosic material consisting of about 17% cellulose, 28% non-cellulosic polysaccharides, mostly arabinoxylan and about 28% lignin. Due to the high content of protein (about 20% on dry matter) and fiber (about 70% on dry matter), as well as phenolic compounds and some minerals, it is a very attractive and nutritionally valuable addition to the human diet. In practice, it is primarily used as a high-value feed for animals, but it can also be used for the production of biogas, it can be used in biotechnological production (as a substrate for growing microorganisms, in the production of lactic acid, carotenoids, enzymes, biofuels, pharmaceuticals, compost, as a carrier for immobilization of biocatalysts), has a potential application as a biosorbent for the removal of pollutants from water, can be used for the production of packaging materials, etc. It is estimated that more than 3.4 million tons of spent grains is produced annually in the European Union, which today is primarily used for livestock feed and thus indirectly contributes to the increase in the level of greenhouse gases in the atmosphere. This extremely valuable and very cheap raw material has a scientifically proven and extremely high potential to be much more than just animal feed. With the development of technology, the increase in energy prices and a generally higher awareness of care for the environment and the consequent recycling of waste, the spent grains is a raw material that in the near future can be both very profitable and very useful in many ways.

# KORIŠĆENJE UGLJENDIOKSIDA KAO POTENCIJALNO REŠENJE ZA PIVARSKU INDUSTRIJU

Aleksa Kojčinović<sup>1</sup>, Anže Prašnikar<sup>1</sup>, Miha Grilc<sup>1</sup>, Blaž Likozar<sup>1</sup>

Postoji nekoliko sektora u kojima se emisija CO<sub>2</sub> ne može lako izbeći (transport, energija, proizvodnja cementa, itd.). Stoga drugi sektori moraju da nadoknade razliku. Industrija hrane i pića, uz hemijsku industriju, pruža mogućnost da se organski otpad pretvori u energiju, kroz anaerobnu digestiju da bi se proizveo metan za grejanje i proizvodnju električne energije. Proces sagorevanja metana treba da se koristi da bi se dobio CO<sub>2</sub> visoke čistoće pored drugih izvora CO<sub>2</sub> kao što je fermentacija. Ova vrsta CO<sub>2</sub> ima stratešku prednost jer je biogena i može se dokazati da je nefosilni izvor ugljenika određivanjem odnosa 14C/12C. Lako uskladišteni proizvodi kao što je metanol mogu se proizvesti iz CO<sub>2</sub> korišćenjem H<sub>2</sub> da bi se vratio u sistem kao proizvod sa dodatom vrednošću. Pored toga, aromatična jedinjenja dobijena iz biomase mogu da se podvrgnu karboksilaciji i da proizvedu različite aromatične karboksilne kiseline, koje nalaze primenu u različitim industrijama, kao što su poljoprivreda, medicina, kozmetika, i pre svega, u proizvodnji antiinflamatornog leka, aspirina. Povezivanje sinteze metanola je takođe moguće sa tačke gledišta upravljanja toplotom - reakcija CO<sub>2</sub> i H<sub>2</sub> je egzotermna i obezbeđuje 50 kJ/mol proizvedenog MeOH, koji bi se mogao koristiti za stvaranje pare. Sve u svemu, "carbon footprint" velike pivare je 100 kg ekv. CO<sub>2</sub>/hL<sup>1</sup>, sa oko 10 kg CO<sub>2</sub>/hL (Balling)<sup>2</sup> koji se stvara samo tokom fermentacije (5 vol.% alc.) i samo delić ove količine gasa je flaširan. Proizvodnja 2.200.000 hL piva 2021. godine u Sloveniji<sup>3</sup>, oslobađa oko 57 t CO<sub>2</sub> dnevno samo fermentacijom. Stoga je moguće korišćenje CO<sub>2</sub>, ali ograničeno unosom energije i infrastrukturom.

U našem radu fokusirali smo se na dva procesa: sintezu metanola i karboksilaciju različitih aromatika dobijenih iz biomase. Sinteza metanola će uključivati mehanizme deaktivacije katalizatora, detaljno kinetičko modeliranje i poboljšanu sintezu metanola. In situ sistemi za uklanjanje proizvoda, kao što su reaktori poboljšani membranom, mogli bi imati veliki potencijal u malom obimu, jer je potrebno manje opreme za prevazilaženje termodinamičkih ograničenja. Nadalje, karboksilacija aromatičnih jedinjenja će detaljno opisati različite postupke pripreme ovog dvostepenog procesa, uticaj različitih reakcionih uslova (temperatura, pritisak, opterećenje), primenjenu analitičku proceduru i na kraju mikrokinetički model koji opisuje pomenuti reakcija.

**Ključne reči:** sinteza metanola, Kolbe-Schmitt, fenol, karboksilacija, iskorišćenje ugljen-dioksida

# CARBON DIOXIDE UTILIZATION AS POTENTIAL SOLUTION FOR BREWING INDUSTRY

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There are several hard to abate emission sectors (transport, energy, cement production, etc.) where CO<sub>2</sub> cannot be easily avoided. Therefore, other sectors have to make up for the difference. The food and beverage industry, alongside the chemical industry, could be a carbon sink where organic waste could be converted into energy, through anaerobic digestion to produce methane for heating and electricity generation. The methane oxy-combustion process needs to be used in order to obtain high purity CO<sub>2</sub> alongside other CO<sub>2</sub> sources such as from fermentation. This type of CO<sub>2</sub> has a strategic advantage as it is biogenic and can be proven to be a non-fossil carbon source by determining the 14C/12C ratio. Easily stored products such as methanol can be produced from CO<sub>2</sub> using H<sub>2</sub> to return it to the system as a value-added product. Additionally, biomass-derived aromatic compounds can undergo carboxylation and produce various aromatic carboxylic acids, which find use in various industries, such as agriculture, medicine, cosmetics, and most notably, in production of the anti-inflammatory drug, aspirin. The coupling of methanol synthesis is also possible from a heat management point of view -the reaction of CO<sub>2</sub> and H<sub>2</sub> to methanol is exothermic and provides 50 kJ/mol of MeOH produced, which could be used to generate steam for the mashing process. Overall, the carbon footprint of a large brewery is 100 kg eq. CO<sub>2</sub>/hL<sup>1</sup>, with about 10 kg CO<sub>2</sub>/hL (Balling)<sup>2</sup> generated only during fermentation (5 vol.% alc.) and only a fraction of this gas amount bottled. The production of 2,200,000 hL of beer in 2021 in Slovenia<sup>3</sup>, mainly in Laško, releases about 57 tonnes of CO<sub>2</sub> per day from fermentation alone. Therefore, large-scale CO<sub>2</sub> utilisation is possible, but limited by energy input and infrastructure.

In our work, we have focused on two processes: methanol synthesis and carboxylation of various biomass-derived aromatics. Methanol synthesis will include catalyst deactivation mechanisms, detailed kinetic modelling and membrane-based enhanced methanol synthesis. In situ product removal systems, such as membrane-enhanced reactors, could have great potential on a small scale, as less equipment is required to overcome thermodynamic constraints. Furthermore, the carboxylation of the aromatic compounds will describe in detail various preparation procedures of this two-step process, the influence of various reaction conditions (temperature, pressure, loading), the analytical procedure used, and finally the microkinetic model which describes the mentioned reaction.

**Key words:** methanol synthesis, Kolbe-Schmitt, phenol, carboxylation, carbon



**Acknowledgments:** This research was funded by the Slovenian Research Agency (basic post-doctoral research projects J2-1723 and J2-2492 and research core funding P2-0152).

<sup>1</sup> <https://doi.org/10.1111/jiec.12642>

<sup>2</sup> <https://doi.org/10.1002/j.2050-0416.1990.tb01034.x>

<sup>3</sup> <https://brewersofeurope.org/uploads/mycms-files/documents/publications/2022/european-beer-trends-2022.pdf>

<sup>4</sup> Energ Effic, 7, 2014, p. 791-810



# EKSTRAKT HMELJA KAO AKTIVNA KOMPONENTA U FILMOVIMA NA BAZI HITOZANA ZA PAKOVANJE HRANE

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Hitozan je derivat hitina, drugog najzastupljenijeg polisaharida na zemlji. Uglavnom se dobija iz egzoskeleta rakova i škampa i predstavlja netoksičan, biorazgradiv i biokompatibilan biopolimer, sa selektivnim antimikrobnim i obećavajućim antioksidativnim aktivnostima. Budući da poseduje dobar kapacitet za formiranje filma, hitozan je stavljen u fokus kao potencijalna sirovina za pripremu ekološki prihvatljivih aplikacija za pakovanje hrane. Filmovi na bazi hitozana se obično pripremaju metodama livenja nakon čega sledi sušenje na umerenim temperaturama. Ugrađivanjem komponenti sa visokim antioksidativnim i/ili antimikrobnim svojstvima u filmove hitozana, možemo povećati njihov zaštitni kapacitet i druga korisna svojstva za pakovanje aktivne hrane. Ekstrakt hmelja (*Humulus lupulus* L.), dobro poznat u pivarskoj industriji, bogat je izvor jedinjenja kao što su  $\alpha$ - i  $\beta$ -kiseline i ksantohumul, koji poseduju visoko antioksidativno i antibakterijsko dejstvo. Stoga, ekstrakti hmelja imaju potencijal da se primenjuju kao prirodni konzervansi za produženje roka trajanja kvarljivih namirnica.

U našem radu, ekstrakt hmelja (HE) je ugrađen u filmove na bazi hitozana. Pripremljeni filmovi su se odlikovali strukturnim, fizičko-hemijskim i antibakterijskim svojstvima. Morfološke i spektroskopske analize su potvrdile uspešnu inkorporaciju HE u polimernu matricu, što je uticalo na strukturu i vizuelni izgled filmova. Prisustvo HE je izazvalo smanjenje hidrofилnog karaktera filmova i obezbedilo potpunu blokadu UV svetlosti na talasnim dužinama ispod 350 nm. Opadajući trend zatezne čvrstoće i Jangovog modula, kao i uzlazni trend izduženja pri kidanju, primećeni su nakon ugradnje ekstrakta. Sadržaj ukupnog fenola u filmovima iznosio je do 13 mg GAE po g filma. Filmovi napunjeni HE su pokazali antibakterijsku aktivnost protiv *Bacillus subtilis*, koji je istaknuti patogen koji se prenosi hranom. Rezultati pokazuju dobru strategiju za diversifikaciju postojećih sirovina za hranu, kao i indikaciju novih mogućih prihoda od sporednih tokova proizvodnje hmelja.

**Ključne reči:** ekstrakt hmelja, filmovi na bazi hitozana, karakterizacija filma, aktivna ambalaža za hranu.

# HOP EXTRACT AS AN ACTIVE COMPONENT IN CHITOSAN-BASED FILMS FOR FOOD PACKAGING

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Chitosan is a derivative of chitin, the second most abundant polysaccharide on Earth. It is mainly recovered from exoskeletons of crabs and shrimps and is a non-toxic, biodegradable, and biocompatible biopolymer, with selective antimicrobial and promising antioxidant activities. Since it has a good film-forming capacity, chitosan has been placed in focus as prospective raw material for the preparation of eco-friendly food packaging applications. Chitosan-based films are commonly prepared by casting methods followed by drying at moderate temperatures. By incorporation of components with high antioxidant and/or antimicrobial properties in chitosan films, we can boost their protective capacity and other beneficial properties for active food packaging. Hop extract (*Humulus lupulus* L.), well-known as bittering agent in brewing industry, is a rich source of compounds such as  $\alpha$ - and  $\beta$ -acids and xanthohumol, that all possess high antioxidant and antibacterial activities. Therefore, hops extracts have the potential to be applied as natural preservatives for extending the shelf life of perishable foods.

In our contribution, hop extract (HE) was incorporated in chitosan-based films. Prepared films were characterized by structural, physicochemical, and antibacterial properties. The morphology and spectroscopic analyses have confirmed successful incorporation of HE into the polymer matrix, which affected the films' structure and visual appearance. The presence of HE has caused a reduction in the hydrophilic character of films and provided a complete UV light blockage at wavelengths below 350 nm. A declining trend of tensile strength and Young's modulus, as well as an ascending trend of elongation at break, have been observed after the extract incorporation. The content of total phenolic in the films was up to 13 mg GAE per g film. The HE-loaded films exhibited antibacterial activity against *Bacillus subtilis*, which is a prominent foodborne pathogen. The results demonstrate a good strategy for diversification of existing food related feedstocks, as well as indicating new possible revenues from side streams of hop production.

**Key words:** hop extract, chitosan-based films, film characterisation, active food packaging.

**Acknowledgment:** Cofounded by the European projects, REMEDIES (GA 101093964), Ruralities (GA 101060876) and Interreg Central Europe TeBiCe (project number CE0100433).



# PRIMENA SEMENKI KOMINE GROŽĐA TOKOM PROCESA FERMENTACIJE I NJIHOV UTICAJ NA PROFIL FENOLNIH JEDINJENJA PIVA

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Pivo je jedno od najpopularnijih alkoholnih pića na svetu i pravi se od prirodnih sastojaka kao što su sladu (*Hordeum vulgare*), hmelj (*Humulus lupulus* L.), voda i kvasac. Danas potrošači zahtevaju razvoj fermentisanih napitaka koji imaju pozitivan uticaj na njihovo zdravlje, podstičući inovacije u tehnologiji piva za korišćenje voća u proizvodnji piva. Većina piva napravljenih sa voćnim aditivima ima veće koncentracije polifenola, povećanu antioksidativnu aktivnost i poboljšana senzorna svojstva. Međutim, potencijal korišćenja voćnog otpada u proizvodnji piva je još uvek slabo istražen. Sa druge strane, proces proizvodnje vina stvara značajnu količinu nusproizvoda bogatih fenolnim jedinjenjima. Seme komine grožđa je odličan izvor flavan-3-ola, procijanidina i fenolnih kiselina koje deluju antioksidativno i na taj način pozitivno utiču na zdravlje ljudi i smanjuju rizik od razvoja hroničnih bolesti kao što su rak, dijabetes, upalne i kardiovaskularne bolesti. Do sada su ekstrakti semenki grožđa uspešno ugrađivani u različite prehrambene proizvode, kao što su kozje mleko, jogurt, sladoled ili fermentisane suve kobasice, doprinoseći poboljšanju njihovih antioksidativnih i nutritivnih svojstava, bez negativnih organoleptičkih efekata. Zbog toga je cilj ovog istraživanja bio da se proizvede pivo sa poboljšanim profilom fenolnih jedinjenja korišćenjem imobilisanih kvasaca i semena komine grožđa sorte Prokupac. Dodavanje semenki komine grožđa tokom procesa fermentacije poboljšalo je fenolni profil piva kvalitativno i kvantitativno. Pivo je obogaćeno elaginskom kiselinom, flavan-3-olima i fenolnim kiselinama koji mogu značajno doprineti njegovim antioksidativna svojstva.

**Ključne reči:** semenke komine grožđa, obogaćivanje piva, fenolna jedinjenja

# THE APPLICATION OF GRAPE POMACE SEEDS DURING THE FERMENTATION PROCESS AND ITS IMPACT ON PHENOLIC PROFILE OF THE BEER

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Beer is one of the most popular alcoholic beverages in the world and is made from natural ingredients such as malted barley (*Hordeum vulgare*), hops (*Humulus lupulus* L.), water, and yeast. Nowadays, consumers are demanding the development of fermented beverages that have a positive impact on their health, driving innovation in brewing technology to use fruits in beer production. Most beers made with fruit additives have higher concentrations of polyphenols, increased antioxidant activity and improved sensory properties. However, the potential of using fruit waste in beer production is still poorly explored. On the other hand, wine-making process generates a significant amount of by-products rich in phenolic compounds. Grape pomace seeds are an excellent source of flavan-3-ols, procyanidins and phenolic acids which have an antioxidant effect and thus have a positive impact on human health and reduce the risk of developing chronic diseases such as cancer, diabetes, inflammatory and cardiovascular diseases. So far, grape seed extracts have been successfully incorporated into various food products, such as goat milk, yogurt, ice cream or fermented dry sausages contributing to the improvement of their antioxidant and nutritional properties, without having negative organoleptic effects. Therefore, the aim of this study was to produce beer with an improved phenolics profile using immobilized yeasts and grape pomace seeds of the Prokupac variety. The addition of grape pomace seeds during the fermentation process improved the phenolic profile of the beer qualitatively and quantitatively. The beer was enriched with ellagic acid, flavan-3ols and phenolic acids, which may contribute significantly to its antioxidant properties.

**Key words:** grape pomace seeds, beer enrichment, phenolic compounds

**Acknowledgment:** This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Science and Technology Development programme—Research projects of the Republic of Serbia and the People's Republic of China), Contract No. 451-02-1236/2023-05) and the Science Fund of the Republic of Serbia, #GRANT No. 7744714.

# IMOBILIZACIJA ĆELIJA KVASCA U POLISAHARID- PROTEIN SISTEME PRIMENOM TEHNIKE SUŠENJA SMRZAVANJEM

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Proces proizvodnje piva podignut je na viši nivo primenom novih tehnika imobilizacije ćelija kvasca. Pored standardnih materijala za imobilizaciju ćelija uvode se polisaharid-protein sistemi u cilju očuvanja vijabilnosti i zaštite ćelija u toku procesa fermentacije. Cilj ovog rada je imobilizacija ćelija kvasca (*Saccharomyces cerevisiae*) metodom sušenja smrzavanjem (liofilizacijom). U tu svrhu korišćeni su 1.5% rastvor alginata niske viskoznosti kao i smeša alginata i izolata proteina surutke u odnosu 1:1. Nakon imobilizacije, za dobijene prahove sa kulturom određena je vijabilnost ćelija, sadržaj vlage, rastvorljivost, srednji prečnik čestica i površinsko naelektrisanje. Morfološke karakteristike utvrđene su primenom skenirajuće elektronske i optičke mikroskopije. Rezultati su pokazali da dodatak proteina utiče na smanjenje sadržaja valage (Alg 9.0±0.15%; Alg-WPI 8.5±0.08%) u uzorcima, dok se rastvorljivost sa dodatom izolata smanjuje. Vrednosti za sadržaj vlage ukazuju da su pomenuti sistemi mikrobiološki stabilni i pogodni za dalju primenu u prehrambenoj industriji. Srednji prečnik čestica sa imobilisanim ćelijama bio je veći nego u kontrolnom uzorku sa slobodnim ćelijama. U uzorcima sa dodatkom proteina surutke primetno je blago povećanje prečnika čestica (Alg 5.4 ±0.97µm; Alg-WPI 5.9±0.49 µm), što se može objasniti povećanjem viskoznosti polaznog rastvora sa izolatom. Površinsko naelektrisanje svih uzoraka je analizirano kako bi se potvrdila fizičko-hemijska stabilnost sistema sa ćelijama. Utvrđeno je da svi uzorci imaju negativno površinsko naelektrisanje, dok niske vrednosti u kontrolnom uzorku ukazuju na sklonost slobodnih ćelija ka agregaciji što je potvrđeno i optičkom mikroskopijom. SEM mikrografijom uzoraka je pokazana uspešnost postupka imobilizacije ćelija kao i da dodatak izolata proteina utiče na smanjenje poroznosti sistema. Rezultati ukazuju da je tehnika sušenja smrzavanjem pogodna za imobilizaciju ćelija uz mogućnost primene na industrijskom nivou, gde je poželjna velika produktivnost procesa uz maksimalnu zaštitu ćelija. Protein-polisaharid sistemi pružaju adekvatnu zaštitu ćelija i imaju potencijal za primenu u industriji piva.

**Ključne reči:** imobilizacija, pivski kvasac, alginat, izolat proteina surutke, liofilizacija



Ovaj rad je podržan od strane Ministarstva nauke, tehnološkog razvoja i inovacija Republike Srbije (PROGRAM RAZVOJ NAUKE I TEHNOLOGIJE – ZAJEDNIČKO FINANSIRANJE RAZVOJNIH I ISTRAŽIVAČKIH PROJEKATA REPUBLIKE SRBIJE I NARODNE REPUBLIKE KINE, Evidencioni broj Aneksa II Ugovora: 451-02-1236/2023-05).



# IMMOBILIZATION OF YEAST CELLS IN THE POLYSACCHARIDE-PROTEIN SYSTEMS USING FREEZE-DRYING TECHNIQUE

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Beer production process has been raised to a higher level by the application of new yeast cell immobilization techniques. In addition to standard materials for cell immobilization, polysaccharide-protein systems are emerging, aiming to preserve viability and improve cell protection during a fermentation process. The main objective of this work was the immobilization of yeast cells (*Saccharomyces cerevisiae*) by the freeze-drying technique (lyophilization). For this purpose, a 1.5% solution of low-viscosity alginate was used, as well as a mixture of alginate and whey protein isolate in a ratio of 1:1. After the process of lyophilization, the obtained powders with immobilized culture were analyzed in terms of cell viability, moisture content, sample solubility, mean particle diameter, and surface charge. Morphological characteristics were determined using scanning electron and optical microscopy. The obtained results showed that the addition of protein reduced the moisture content (Alg 9.0±0.15%; Alg-WPI 8.5±0.08%) in the samples, while the solubility decreased with the addition of the isolate. The low values for the moisture content indicate that the polysaccharide-protein systems are microbiologically stable and suitable for further application in the food industry. It is noticeable that the average diameter of the immobilized yeast cell was larger than that of the nonimmobilized cell. Samples with addition of whey protein result in slight variations of diameter (Alg 5.4 ±0.97µm; Alg-WPI 5.9±0.49µm), which can be explained by an increase in the viscosity of the initial solution with the isolate. The surface charge of all samples was determined to confirm the physico-chemical stability of the system with immobilized cells. Negative surface charge was found in all samples, but low values in the control sample indicate the tendency of free cells to aggregate, which was also confirmed by optical microscopy. SEM micrographs showed successful cell immobilization as well as reduced system porosity in the samples with the addition of protein isolate. The results indicate that the freeze-drying technique is suitable for cell immobilization, with the possibility of application at the industrial level where high productivity of the process with maximum cell protection is desired. Protein-polysaccharide systems provide suitable cell protection and have potential for application in the beer industry.

**Keywords:** immobilization, brewery yeast, alginate, whey protein isolate, lyophilization

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (SCIENCE AND TECHNOLOGY DEVELOPMENT PROGRAMME–RESEARCH PROJECTS OF THE REPUBLIC OF SERBIA AND THE PEOPLE'S REPUBLIC OF CHINA, Contract No. 451-02-1236/2023-05)



# PRIMENA ALGINAT-HITOZAN MIKROKAPSULA SA TEČNIM JEZROM U ŠARŽNOJ I KONTINUIRANOJ PROIZVODNJI PIVA

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Tehnologija imobilizovanih ćelija je uspešno primenjena u industrijskoj proizvodnji piva sa smanjenim sadržajem alkohola i sazrevanjem piva, ali još uvek nije široko primenjena u fermentaciji zbog promenjenog metabolizma i ukusa, kao i cene nosača. Cilj ovog rada je da se ispituju mogućnosti primene alginat-hitozanskih mikrokapsula sa tečnim jezgrom u šaržnoj i kontinuiranoj fermentaciji piva na laboratorijskoj skali. U tu svrhu, lager soj kvasca *Saccharomyces pastorianus* (*carlsbergensis*) Saflager S-23 imobilisan je u pomenute mikrokapsule i korišćen za šaržnu fermentaciju u plastičnim bocama, opremljenim sistemom vazdušnih komora. U našoj prethodnoj studiji dobijeni su sledeći optimizovani uslovi fermentacije: originalni ekstrakt –  $9,72 \pm 0,5^\circ\text{P}$ ; temperatura glavne fermentacije –  $16 \pm 0,5^\circ\text{S}$ ; temperatura sazrevanja –  $20 \pm 0,5^\circ\text{S}$ ; masa imobilisanih ćelija –  $12,71 \pm 0,2$  g. Ukupno vreme fermentacije je bilo 156 h i proizvedeno pivo je bilo senzornog profila u poređenju sa dva konvencionalna piva proizvedena u bugarskim pivarama. Šaržna fermentacija je prevedena u kontinuiranu glavnu fermentaciju sa imobilisanim ćelijama u bioreaktoru sa nabijenim slojem, pod istim uslovima fermentacije, sa izuzetkom mase imobilizovanih ćelija koja je povećana na 48 g. Stopa razblaženja je optimizovana na  $0,0163 \text{ h}^{-1}$ . Sistem je radio u neprekidnom režimu 10 dana. „Zeleno“ pivo je imalo senzorni profil uporediv sa drugim pivima koje proizvode imobilisane ćelije u hidrogelovima. Sazrevanje je obavljeno sa slobodnim ćelijama koje su iscurile iz perli alginat-hitozana. Rezultati za sekundarne metabolite proizvedenog piva upoređeni su sa rezultatima istih konvencionalnih piva. Pivo proizvedeno kontinuiranom fermentacijom pokazalo je veću koncentraciju etil acetata i acetaldehida od konvencionalnih piva. Što se tiče viših alkohola, došlo je do povećanja koncentracije 1-propanola i smanjenja koncentracije 1-butanola i 3-metilbutanola, ali je visok prag viših alkohola učinio ove razlike neznatnim. Može se zaključiti da je profil ukusa piva proizvedenog kontinuiranom fermentacijom bio sličan konvencionalnom pivu. Dakle, biće moguće proširiti tehnologiju na pilot nivo nakon što podaci iz tehno-ekonomskih procena potvrde efikasnost ove tehnologije.

**Ključne reči:** imobilizovane ćelije, šaržna fermentacija, kontinuirana fermentacija, lager kvasac, senzorni profil

# APPLICATION OF ALGINATE-CHITOSAN MICROCAPSULES WITH LIQUID CORE IN BATCH AND CONTINUOUS BEER PRODUCTION

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Immobilized cell technology has been implemented successfully in the industrial production of beer with reduced alcohol content and beer maturation, but have not yet been widely adopted in main fermentation because of the changed metabolism and flavour, and the carrier price. The aim of this study was to investigate the possibilities for the application of alginate-chitosan microcapsules with liquid core in batch and continuous beer fermentation in a laboratory scale. For this purpose, lager yeast strain *Saccharomyces pastorianus (carlsbergensis)* Saflager S-23 was immobilized in the aforementioned microcapsules and used for batch fermentation in plastic bottles, equipped with an airlock system. The following optimized fermentation conditions were obtained in our previous study: original extract –  $9.72 \pm 0.5^\circ\text{P}$ ; main fermentation temperature –  $16 \pm 0.5^\circ\text{C}$ ; maturation temperature –  $20 \pm 0.5^\circ\text{C}$ ; mass of immobilized cells –  $12.71 \pm 0.2$  g. The total fermentation time was 156 h and beer produced was with sensory profile compared to 2 conventional beers produced by Bulgarian breweries. The batch fermentation was transferred to continuous main fermentation with immobilized cells in packed bed bioreactor under the same fermentation conditions, with the exception of mass of immobilized cells, which was increased to 48 g. The dilution rate was optimized to  $0.0163 \text{ h}^{-1}$ . The system worked in a continuous mode for 10 days. The “green” beer had a sensory profile comparable to the other beers produced by immobilized cells in hydrogels. Maturation was carried out with free cells which leaked from the alginate-chitosan beads. The results for secondary metabolites of beer produced were compared to the results of the same conventional beers. Beer produced by continuous fermentation showed higher concentration of ethyl acetate and acetaldehyde than the conventional beers. Regarding the higher alcohols, there was an increase in the concentration of 1-propanol and a decrease in that of 1-butanol and 3-methylbutanol, but the high threshold of the higher alcohols rendered these differences non-significant. It can be concluded that the flavour profile of beer produced by continuous fermentation was similar to the conventional beers. Therefore, it will be possible to scale up the technology to a pilot level after the data from techno-economic evaluations confirm the effectiveness of this technology.

**Key words:** immobilized cells, batch fermentation, continuous fermentation, lager yeast, sensory profile



# VREDNOVANJE EKSTRAKATA *PRUNUS SPINOSA* L. KAO FUNKCIONALNIH SASTOJAKA U ALKOHOLNIM PIĆIMA

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Kontinuirani rast tržišta piva i alkoholnih pića otvorio je nove mogućnosti za poboljšanje ukusa, arome i korisnosti ovih napitaka. Već hiljadu godina unazad je poznato da dodavanje različitih biljnih sastojaka u piće menja njihov ukus i svojstva. Međutim, moderna tehnologija olakšava postizanje željenih karakteristika i nudi nove mogućnosti za terapijske efekte i senzorna poboljšanja ovog tradicionalnog pića. U ovom radu su predstavljene hemijska analiza i bioaktivna svojstva etanolnog i vodenog ekstrakta *Prunus spinosa* L. (trnjine) kao potencijalnog dodatka pivu, sa ciljem povećanja funkcionalnih karakteristika i senzornih osobina ovog napitka. Hemijske analize korišćenjem UHPLC-QToF-MS pokazale su prisustvo: derivata hidroksibenzojeve kiseline (heksozid vanilinske kiseline do 141.476 mg/100 g ekstrakta), derivata hidroksicimetne kiseline (izomer kafeoilkvske kiseline do 306.608 mg/100 g ekstrakta, feruloilkvske kiseline do 225.884 mg/100 g ekstrakta) i derivata flavona (apigenin 180.094 mg/100g ekstrakta). Procena bioaktivnih svojstava nesumnjivo je pokazala da oba ekstrakta trnjine imaju umeren do dobar antimikrobni potencijal, kao i sposobnost da inhibiraju formiranje biofilma, pri čemu je etanolni ekstrakt pokazao sveukupni bolji potencijal u inhibiciji rasta mikroorganizama. Najbolji antimikrobni potencijal je pokazan kod vodenog ekstrakta prema *Bacillus cereus* koja je poznati patogen identifikovan u namirnicama (MIC 0.5 mg/mL, MBC 1.00 mg/mL), dok su druge testirane bakterije bile otpornije na aktivnost testiranih ekstrakata (MIC u opsegu od 1.0- 4.0 mg/mL i MBC u opsegu od 2.00-8.00 mg/mL). Rezultati antifungalne aktivnosti su pokazali da ekstrakti prilično ujednačeno deluju inhibitorno na rast testiranih mikrogljiva, uz MIK vrednosti 1.00 mg/mL i MFK 2.00 mg/mL. Detaljnija analiza antimikrobne aktivnosti pokazala je da testirani ekstrakti trnjine značajno inhibiraju formiranje biofilma *Candida albicans* ATCC 10231; oba testirana uzorka su inhibirala formiranje biofilma na subinhibitornim koncentracijama približno 67.00 %. Uočena aktivnost se može pripisati prisustvu različitih fenolnih jedinjenja. Imajući u vidu poznat gorak ukus *P. spinosa* kao i pokazana bioaktivna svojstva njegovih ekstrakata, verujemo da bi ova biljka bila odličan funkcionalni sastojak koji će se dobro uklopiti u jedinstvena senzorna svojstva piva i sličnih napitaka. Predloženo pivo bi čak moglo da pruži dodatne zdravstvene efekte potrošačima,

balansirajući između zadovoljstva i njihove želje za zdravim sastojcima.

**Ključne reči:** *Prunus spinosa*; etanolni ekstrakt, vodeni ekstrakt, bioaktivna svojstva, funkcionalni sastojak;

# VALORIZATION OF *PRUNUS SPINOSA* L. EXTRACTS AS FUNCTIONAL INGREDIENTS IN ALCOHOLIC BEVERAGES

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The continuous growth of beer and beverage market has opened new opportunities to improve their flavor, aroma, and benefits. It has been known for thousands of years that adding various herbs to beer changes the taste and properties of this beverage. However, modern technology makes it easier to achieve the desired properties and provides useful qualities for therapeutic effects and sensory improvement of traditional beer. This paper presents chemical analysis and bioactive properties of ethanolic and aqueous extract of *Prunus spinosa* L. (blackthorn) as a potential ingredient for beer to improve functional and sensory properties of this beverage. Chemical analyses by UHPLC-QToF-MS revealed presence of: hydroxybenzoic acid derivatives (vanillic acid hexoside up to 141.476 mg/100g extract), hydroxycinnamic acid derivatives (caffeoylquinic acid isomer up to 306.608 mg/100g extract and feruloylquinic acid up to 225.884 mg/100g extract) and flavone derivatives (apigenin 180.094 mg/100g extract). The evaluation of bioactive properties undoubtedly showed that both blackthorn extracts have moderate to rather good antimicrobial and antibiofilm potential, with ethanolic extract being slightly better in terms of inhibiting microbial growth. The best antimicrobial potential was observed with aqueous extract towards foodborne pathogenic bacteria *Bacillus cereus* (MIC 0.5 mg/mL, MBC 1.00 mg/mL), whereas other tested bacteria were more resilient towards the activity of the tested extracts (MIC in range of 1.0-4.0 mg/mL and MBC in range of 2.00-8.00 mg/mL). In terms of antifungal potential, the extracts showed rather uniform inhibitory effects towards tested microfungi with MIC value 1.00 mg/mL and MFC 2.00 mg/mL. A more in depth analysis of antimicrobial activity showed that the tested blackthorn extracts have promising antibiofilm activity towards *Candida albicans* ATCC 10231 as well, with both samples inhibiting formation of biofilm at subinhibitory levels approximately 67.00 %. Observed activity may be attributed to the presence of various phenolic compounds. Considering the well-known bitter taste of *P. spinosa* and demonstrated bioactive properties of its extracts, we believe it would be a great functional ingredient to add to the unique sensory properties of beer and similar beverages. This beer may even be able to provide consumers with additional health benefits, balancing enjoyment with the desire for healthy ingredients.

**Keywords:** *Prunus spinosa*; ethanolic extract, aqueous extract, bioactive properties; functional ingredients;

**Acknowledgment:** This work has been supported by the Serbian Ministry of Science, Technological Development and Innovation (Grants: 451-03-68/2023-14/200007) and the Science and Technology Development programme–Research projects of the Republic of Serbia and the People's Republic of China (Contract No. 451-02-1236/2023-05) and the Science Fund of the Republic of Serbia, #GRANT No. 7744714.

# ISKORIŠĆENJE OTPADNOG PIVSKOG KVASCA ZA INKAPSULACIJU BIOAKTIVNIH KOMPONENATA HRANE

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Otpadni pivski kvasac (OPK) (engl. Spent brewer's yeast, SBY) drugi je najvažniji nusproizvod industrije piva nakon pivskog tropa. Premda se neki kvasci mogu koristiti više puta za fermentaciju sladovine, nastala biomasa se na kraju proizvodnog procesa odbacuje, što dalje uzrokuje finansijske i ekološke probleme. U cilju smanjenja otpada ovog nusproizvoda agroindustrije, OPK se uglavnom koristi kao stočna hrana i kao takav ima nisku komercijalnu vrednost. Međutim, zbog svoje visoke nutritivne vrednosti, visoke dostupnosti i niske cene, OPK ima potencijal za profitabilnije primene, između ostalog, i za inkapsulaciju bioaktivnih jedinjenja. Sastav ćelijskog zida kvasca omogućava inkapsulaciju i hidrofилnih i lipofilnih bioaktivnih supstanci, dok njegova mehanička svojstva pružaju zaštitu od spoljnih faktora tokom obrade, skladištenja i konzumiranja. Proces inkapsulacije primenom otpadnog pivskog kvasca je jednostavan i rezultuje visokom efikasnošću inkapsulacije, koja se dodatno može poboljšati različitim predtretmanima kvašćevog materijala. Jedinjenja do sada uspešno inkapsulirana u OPK i materijale dobijene iz OPK uključuju polifenole, vitamine, ulja, pa čak i probiotike. U pogledu mogućih primena, OPK inkapsulati imaju veliki potencijal za upotrebu u prehrambenoj industriji; mogu se koristiti u formulaciji funkcionalne hrane ili kao zdrava zamena za sintetičke konzervanse i/ili boje. Ipak, povišeni troškovi proizvodnje i, u nekim slučajevima, gorčina inkapsulata mogu predstavljati izazov kada je u pitanju šira primena ove tehnologije i stoga bi trebalo da budu u fokusu budućih studija.

**Ključne reči:** otpadni pivski kvasac, nusproizvod, inkapsulacija, nosač

# UTILIZATION OF SPENT BREWER'S YEAST FOR ENCAPSULATION OF FOOD BIOACTIVES

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Spent brewer's yeast (SBY) is the second most important by-product in the brewing industry after spent grain. Although some yeasts can be used multiple times to ferment wort, the resulting biomass is discarded at the end of the production process, causing financial and environmental problems. To reduce the waste of this agro-industrial by-product, SBY is mainly used as animal feed and, as such, it has low commercial value. However, due to its high nutritional value, high availability, and low cost, SBY has the potential for more profitable applications, including the encapsulation of bioactive compounds. The composition of the yeast cell wall allows for the entrapment of both hydrophilic and lipophilic bioactives, while its mechanical properties provide protection from external factors during processing, storage, and consumption. The process of encapsulation with spent brewer's yeast is simple and leads to high encapsulation efficiency, which can be further improved by various pretreatments of the yeast material. Compounds that have been successfully encapsulated in SBY and SBY-derived materials to date include polyphenols, vitamins, oils, and even probiotics. In terms of possible applications, SBY encapsulates have great potential for use in the food industry; they can be used to develop functional foods or as healthy substitutes for synthetic preservatives and/or colorants. However, higher production costs and, in some cases, the bitterness of the encapsulates may pose a challenge to wider application of this technology and should therefore be the focus of future studies.

**Keywords:** spent brewer's yeast, by-product, encapsulation, carrier material

**Acknowledgments:** This work was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant number: 451-03-47/2023-01/200116).



# MODELI ZA PREDVIĐANJE UTICAJA KLIMATSKIH PROMENA NA SASTAV BIOAKTIVNIH KOMPONENTI HMELJA

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Klimatske promene smatraju se jednim od najvećih izazova današnjice. Globalno otopljavanje, pojava poplava, snažnih vetrova i dugih sušnih perioda imaju negativne posledice na prinos i kvalitet gajenih biljaka, kao i na očuvanje genetičkih resursa i biodiverziteta u celini. Adaptivni odgovori različitih biljnih vrsta na klimatske promene su veoma složeni, uključujući promene metaboličkih puteva i akumulaciju specifičnih bioaktivnih jedinjenja radi povećanja otpornosti na stres spoljašnje sredine. Hmelj (*Humulus lupulus* L.) potiče iz područja Evroazije i prema svojim morfološkim, ekološkim i biogeografskim karakteristikama pripada grupi mezofitnih biljaka koje su umereno tolerantne na nedostatak vlage i povišene temperature. Kvalitet hmelja se vezuje za sastav i količinu gorkih alfa i beta kiselina, tj. humulona i lupulona koji pripadaju grupi tzv. prenilovanih floroglucinolskih derivata. Cilj našeg istraživanja je bio da se utvrdi efekat klimatskih parametara, posebno padavina i temperatura, na koncentraciju ključnih sekundarnih metabolita hmelja u okviru višegodišnjeg ogleda sa sedam različitih sorti gajenih na proizvodnim parcelama Petrovec d.o.o. Metodom gasne hromatografije (GC/MS) i tečne hromatografije visokih performansi (HPLC) određena je koncentracija ukupno 16 jedinjenja izolovanih iz zrelih šišarica hmelja. Radi razumevanja mogućih uticaja klimatskih varijabli na kvalitet sirovine hmelja primenjeno je biostatističko modelovanje. Ispitivanje zavisnosti uticaja pojedinačnih parametara klime na količinu bioaktivnih molekula hmelja u većini slučajeva nije dalo zadovoljavajuće rezultate u smislu validacije modela. Stoga su u analizu uvedene sve klimatske varijable istovremeno, prilikom čega je korišćeno više različitih multivarijacionih predikcionih funkcija, kao što su PLS, SVM i PC regresioni modeli. Najbolje predikcione performanse pokazao je PC regresioni model ( $R^2=0,97$ ) primenjen na primeru humulena, tj. alfa kariofilena, karakteristične aromatične komponente hmelja.

**Ključne reči:** gorke kiseline, terpeni, predikcioni biostatistički modeli

# MODELS FOR CLIMATE CHANGE ASSESSMENT FOR THE CONTENT OF BIOACTIVE COMPOUNDS IN HOPS

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Climate change is considered one of the greatest challenges today. Global warming, the occurrence of floods, strong winds, and long periods of drought have significant negative impacts on crop yield and quality, as well as on the conservation of plant genetic resources and biodiversity in general. Adaptive responses to climate change effects of different plant species to climate change impacts are very complex and include changes in metabolic pathways and accumulation of specific bioactive compounds involved in environmental stress tolerance. Common hop (*Humulus lupulus* L.) originates from Eurasian region, and according to its morphological, ecological, and biogeographical characteristics the species is classified in the group of mesophytic species that are moderately tolerant to water deficits and elevated temperatures. The quality of hops is related to the content of bitter acid, i.e. humulones and lupulones, which belong to the prenylated phloroglucinol derivatives. The aim of our study was to assess the effects of climatic parameters, mainly precipitation and temperature, on the concentration of the main secondary metabolites. The multi-year experiment included the testing of the properties of seven different hop varieties and was carried out at the production field of the company Petrovec Ltd in northern Serbia. The concentration of a total of 16 compounds isolated from mature hop cones was determined using standard procedures, i.e. gas chromatography (GC/MS) and high performance liquid chromatography (HPLC). A chemometric approach was applied to evaluate the possible effects of climate on the accumulation of certain bioactive compounds in common hop varieties. The dependence of secondary metabolite accumulation on individual climate parameters could not be established in most cases in terms of model validity. Therefore, the further biostatistical analyses were performed with simultaneous inclusion of all climate variables using different multivariate prediction models such as PLS, SVM and PC regression. The best performances were achieved by the PC regression model ( $R^2=0.97$ ) performed for humulene, i.e. alpha caryophyllene, the typical aromatic terpene in the common hop.

**Keywords:** bitter acids, terpenes, prediction biostatistical models

**Acknowledgement:** The work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia and the Faculty of Agriculture, Belgrade (No: 451-03-47/2023-01/200116).

# HEMIJSKI SASTAV I BIOLOŠKA AKTIVNOST ESENCIJALNIH ULJA I HIDROLATA HMELJA

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U drevnim kulturama su se ženske cvasti (šišarice) hmelja koristile u očuvanju pića sa niskim sadržajem alkohola kojima su davale specifičnu aromu. Danas se koriste u pivarstvu, kozmetičkoj, farmaceutskoj i prehrambenoj industriji. Prema naučnim podacima, hmelj ima sedativno dejstvo a poseduje i značajan antiinflamatorni i antidijabetički potencijal. Glavni biološki aktivni sastojci koji utiču na ove aktivnosti su eterična ulja, gorke materije (alfa i beta-kiseline), fitoestrogeni i flavonoidi (flavonol glikozidi, kondenzovani tanini i prenilflavonoidi). Eterično ulje hmelja je zlatnožuto, sveže i pomalo oštre biljne arome. Komercijalna proizvodnja eteričnih ulja se obavlja destilacijom biljne mase vodom ili vodenom parom. S obzirom na to da je u oba procesa rastvarač voda, ove tehnike ekstrakcije se klasifikuju kao zelena tehnologija. Nakon ekstrakcije eteričnih ulja iz biljnog materijala kao sporedni proizvod se dobijaju čvrsti ostaci (iscrpljeni biljni materijal) i hidrolat.

Hemijski sastav eteričnih ulja i hidrolata hmelja obuhvata više od 80 komponenti. U eteričnom ulju su najdominantniji sastojci mircen i  $\alpha$ -humulen, dok u hidrolatu dominiraju izovalerinska kiselina, 5,5-dimetil-2(5 H)-furanon i linalol. U in vitro testovima eterična ulja hmelja nisu ispoljila značajniji antimikrobni i antioksidativni potencijal, alu usled specifičnog mirisa i ukusa mogu imati široku primenu u industriji hrane i pića. Hidrolati koji se dobijaju kao nusproizvodi prilikom destilacije eteričnih ulja i u poređenju sa njima imaju potpuno drugačiju aromu. Hidrolati takođe ne pokazuju ni antioksidativno ni antimikrobno dejstvo, a zbog svog neprijatnog mirisa nisu pogodni za upotrebu u prehrambenoj industriji.

Testovi koji su se odnosili na potencijalnu upotrebu hidrolata hmelja u poljoprivredi su pokazali značajnu alelopatsku aktivnost na klijavost, dužinu epikotila i hipokotila kod semena kukuruza i nekih korova poput *Amaranthus retroflexus* (svinjača). Rezultati ovih ispitivanja ukazuju na stimulatивно delovanje hidrolata na klijanje krupnozrnih biljaka poput kukuruza. U višim koncentracijama uspešno deluju kao prirodni herbicid na klice sitnozrnih korova.

**Ključne reči:** hmelj, eterično ulje, hidrolat

# CHEMICAL COMPOSITION AND BIOLOGICAL ACTIVITY OF ESSENTIAL OILS AND HYDROLATES OF HOPS

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In ancient cultures, the female flowers (cones) of hops were used to preserve drinks with a low alcohol content to which they gave a specific aroma. Today, they are used in the brewing, cosmetic, pharmaceutical and food industry. According to scientific data, hops have a sedative effect, and have a significant anti-inflammatory and anti-diabetic potential. The main biologically active ingredients that influence these activities are essential oils, bitter substances (alpha and beta-acids), phytoestrogens and flavonoids (flavonol glycosides, condensed tannins and prenylflavonoids). The essential oil of hops is golden yellow, with a fresh and slightly sharp herbal aroma. The commercial production of essential oils is carried out by distilling the plant mass with water or steam. Since water is the solvent in both processes, these extraction techniques are classified as green technology. After the extraction of essential oils from plant material, hydrolate and solid residues (exhausted plant material) and are obtained as by-products.

The chemical composition of essential oils and hop hydrolates includes more than 80 components. Myrcene and  $\alpha$ -humulene are the most dominant ingredients in the essential oil, while isovaleric acid, 5,5-dimethyl-2(5 H)-furanone and linalool dominate in the hydrolate. In in vitro tests, hop essential oils did not show significant antimicrobial or antioxidant potential, but due to their specific smell and taste, they can be widely used in the food and beverage industry. Hydrolates, which are obtained as by-products during the distillation of essential oils, have a completely different aroma. Also, hydrolates do not show either antioxidant or antimicrobial effects, and due to their unpleasant smell, they are not suitable for use in the food industry.

Tests related to the potential use of hop hydrolates in agriculture showed significant allelopathic activity on germination, epicotyl and hypocotyl length in corn seeds and some weeds such as *Amaranthus retroflexus* (pigweed). The results of these tests indicate the stimulating action of the hydrolate on the germination of large-grain plants such as corn. In higher concentrations, they successfully act as a natural herbicide on the sprouts of small-grained weeds.

**Key words:** hops, essential oil, hydrolate

# NOVA SORTA HMELJA IZ BAČKOG PETROVCA ZA PRIMENU U INDUSTRIJI ZANATSKOG PIVA

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Industrija zanatskog pivarstva koja se veoma brzo razvija zavisi, između ostalog, od hemijskog sastava cvasti hmelja (*Humulus lupulus* L.), zvanih šišarice, kao osnovnog sastojka koji određuje ukus piva, ekskluzivnost i jedinstvenost, a koji su veoma cenjeni od strane potrošača zanatskog piva sa sofisticiranim ukusom širom sveta. U 2021, vrednost ubranog hmelja širom sveta bila je ~900 miliona evra. Najveći proizvođači hmelja su SAD i Nemačka. Globalna potražnja za razvojem i upotrebom novih sorti hmelja uglavnom je posledica globalnog povećanja broja zanatskih pivara, koje imaju za cilj da ponude potrošačima ekskluzivna piva jedinstvenog ukusa. U Srbiji su registrovane 3 internacionalne i 3 domaće sorte hmelja koje se danas gaje na oko 8 ha. Oplemenjivanje hmelja u našoj zemlji je, međutim, prestalo 1990-ih. Naši ciljevi su da obnovimo kako oplemenjivanje tako i proizvodnju hmelja, razvojem nove sorte aromatičnog hmelja iz trenutno neiskorišćenog genofonda hmelja (divlji i poludivlji hmelj), za proizvodnju ekskluzivnog i jedinstvenog piva koje će se u početku proizvoditi lokalno, od strane domaćih zanatskih pivara, ali sa potencijalom proširenja proizvodnje/prodaje regionalno i globalno. Naš uspeh zasniva se na dobro poznatoj činjenici da je lokalni divlji i poludivlji hmelj bolje prilagođen lokalnoj klimi, ima bolje prinose i otpornost na štetočine/bolesti, kao i da poseduje neistražen, ali potencijalno veoma vredan hemijski sastav šišarica. Fond za inovacionu delatnost Srbije prepoznao je potencijal naših ideja i odobrio nam sredstva za realizaciju našeg projekta Hopseeker (ID projekta 51815).

Klonski smo razmnožili 18 divljih i poludivljih genotipova hmelja iz Vojvodine, procenili hemijski sastav njihovih šišarica u odnosu na relevantna jedinjenja koja određuju kvalitet i ekskluzivnost piva i proizveli pivo u lokalnim zanatskim pivarama, koje će ocenjivati potrošači i profesionalci. Biljke hmelja koje daju najbolje pivo biće upoređene na genomskom nivou sa međunarodnim i lokalnim sortama, koristeći SNP genomske markere, kako bi se dobio njihov jedinstveni genetski profil, neophodan za zaštitu prava proizvođača i žiga. Registrovaćemo novu sortu aromatičnog hmelja u Srbiji, sa zaštićenom oznakom porekla, koja će zatim biti korišćena za dalje oplemenjivanje i dalji razvoj novih sorti hmelja.

**Ključne reči:** divlji i poludivlji aromatični hmelj, lokalno adaptirani genotipovi, zapostavljen genofond hmelja, zanatsko pivo, intelektualna svojina

**Zahvalnica:** Projekat finansira Fond za inovacionu delatnost iz Pretpristupnih fondova Evropske unije i budžeta Republike Srbije sa razdela Ministarstva prosvete, nauke i tehnološkog razvoja, naziv projekta Hopseeker, broj projekta 51815.



# A NEW AROMA HOP VARIETY FROM BAČKI PETROVAC FOR CRAFT BREWERIES

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Rapidly growing craft brewing industry depends ultimately on the chemical composition of hop (*Humulus lupulus* L.) inflorescences, called hop cones, as an essential ingredient determining beer flavors, exclusivity and uniqueness, that are highly valued by craft beer consumers with sophisticated taste worldwide. In 2021, the value of hops harvested worldwide was ~€900M. The largest hop producers are the US and Germany. The global demand for the development & usage of new hop varieties is mainly due to the global increase in the number of craft breweries, which aim to offer consumers exclusive beers of unique taste. In Serbia, 3 international & 3 local hop varieties are registered, and grown today at ~8 ha. Hop breeding in our country, however, ceased in 1990s. Our aims are to restore both hop breeding and production, by developing a new aroma hop variety from currently untapped hop gene pool (wild and semi-wild hops), for the production of an exclusive and unique beer that will be initially produced locally, by domestic craft breweries, but with the potential to expand the production to regional & global scales. Our success is founded in the well-known fact that local wild & semi-wild hops are better adapted to local climate, have better yields and resistance to pests/diseases, as well as grossly unexplored but potentially very valuable chemical composition of cones, needed for craft brewing industry. The Serbian Innovation Fund recognized the potential of our ideas, and granted us funding (project Hopseeker, project ID 51815).

We clonally propagated 18 wild & semi-wild hops from Vojvodina, assessed the chemical composition of their cones in respect to relevant compounds determining beer quality & exclusivity, and produced beer in local craft breweries, which will be evaluated by consumers & professionals. Hop plants giving the best beer will be compared at the genomic level with the international & local varieties, using SNP genomic markers, to obtain their unique genetic profile, needed for the protection of plant breeders' rights and trademark. They will be registered as a new aroma variety, with Protected Designation of Origin, and used for breeding & further development of new hop varieties.

**Key words:** wild and semi-wild aromatic hops, locally adapted genotypes, genlected hop gene pool, craft beers, intellectual property

**Acknowledgment:** The project is financed by the Innovation Fund from the European Union Pre-Accession Assistance and from the budget of the Republic of Serbia, the line of Ministry of Education, Science and Technological Development, project name: Hopseeker, project ID 51815.



# UTICAJ ZANATSKOG PIVARSTVA NA OŽIVLJAVANJE PROIZVODNJE HMELJA U SRBIJI

Dejan Smiljanić

*The Black Turtle Brewery, Beograd*

U radu je prikazana situacija u kojoj se nalazi proizvodnja hmelja u Srbiji, stanje stvari, ali i perspektive za budući rast. Ukazano je na činjenicu da je poslednjih desetak godina bilo pokušaja sa uzgojem novih sorti hmelja baziranih na entuzijizmu pojedinaca koji su ukazali na potencijal koji ovde postoji. U tom smislu je neohodna jača i sitemska podrška države. Nešto se ipak pokreće putem projekta koji daje podršku istraživanjima novih sorti hmelja, što bi mogao da bude putokaz za revitalizaciju proizvodnje hmelja u Srbiji.

## THE IMPACT OF CRAFT BREWING ON THE REVIVAL OF HOP PRODUCTION IN SERBIA

Dejan Smiljanić

*The Black Turtle Brewery, Belgrade*

The paper presents the state and the prospects for future growth of hop production in Serbia, pointing out that in the last ten years, there have been attempts to grow new varieties of hops based on the enthusiasm of individuals indicating its potential. With this in mind, stronger and systemic support from the state is necessary. Initiative has been shown through a project that supports research into new hop varieties, which could be a guideline for the revitalization of hop production in Serbia.



# AKTUELNA I POTENCIJALNA FINANSIJSKA PODRŠKA DRŽAVE RAZVOJU PROIZVODNJE HMELJA U SRBIJI

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Cilj rada je da se predstavi finansijska podrška države razvoju proizvodnje hmelja na području Republike Srbije. Autori predlažu i potencijalni model finansijske podrške države čija bi svrha bila da se zaustavi pad domaće proizvodnje ove značajne sirovine za razvoj preradnih kapaciteta, kao i za razvoj mini pivara, što je od značaja i za razvoj preduzetništva. U radu se analiziraju izdvajanja iz agrarnog budžeta u protekloj deceniji, usmerena za podsticaje za podizanje novih zasada hmelja. Autori smatraju da bi u cilju razvoja ove proizvodnje, kao i celokupne poljoprivrede u Republici Srbiji, trebalo da se sagledaju mogućnosti za osnivanje specijalizovane poljoprivredne banke, čiji model predlažu, kao razvojne državne finansijske institucije.

**Ključne reči:** finansiranje poljoprivrede, proizvodnja hmelja, agrarni budžet, specijalizovana poljoprivredna banka, Republika Srbija

## CURRENT AND POTENTIAL STATE FINANCIAL SUPPORT FOR THE DEVELOPMENT OF HOPS PRODUCTION IN SERBIA

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The aim of the paper is to present the state's financial support for the development of hop production on the territory of the Republic of Serbia. The authors also propose a potential model of financial support from the state, the purpose of which would be to stop the decline in domestic production of this important raw material for the development of processing capacities, as well as for the development of mini-breweries, which is also important for the development of entrepreneurship. The paper analyzes allocations from the agricultural budget in the past decade, aimed at incentives for raising new hop plantations. The authors consider that in order to develop this production, as well as the entire agriculture in the Republic of Serbia, the possibilities for establishing a specialized agricultural bank, the model of which they propose, should be considered as a development state financial institution.

**Key words:** agricultural financing, hop production, agricultural budget, specialized agricultural bank, Republic of Serbia

# NEKI TEHNOLOŠKI PRISTUPI PROIZVODNJI PIVA SA SMANJENIM SADRŽAJOM ALKOHOLA

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Proizvodnja piva neprestano se razvija, a na tržištu se pojavljuju brojni novi proizvodi, uključujući pića sa smanjenim sadržajem alkohola. Proizvodnja niskoalkoholnog piva ima različite istorijske pozadine. Smanjena proizvodnja sirovina tokom dva svetska rata dovela je do proizvodnje sladovine sa smanjenim početnim ekstraktom, a samim tim i proizvodnje piva sa niskim sadržajem alkohola. Poslednjih godina u EU beleži porast proizvodnje piva sa smanjenim sadržajem alkohola od 50%, a trenutno je ovaj segment tržišta piva u granicama od 4-5%. Ovo je prvenstveno zbog uvedenih ograničenja u pogledu konzumiranja alkohola i traženja novih proizvoda u konkurentskom okruženju. U EU je uvedena kategorizacija piva, a smatra se da niskoalkoholno pivo ne sadrži više od 1,2% (v/v) etanola. Predmet ovog rada bio je razvoj modifikovanih načina proizvodnje piva primenom bioloških pristupa, modifikaciji metoda i načina za fermentaciju. Analizom postojećih metoda za proizvodnju niskoalkoholnog i bezalkoholnog piva predloženi su sledeći pristupi: metode i režimi za dobijanje sladovine sa redukovanim ekstraktom; ograničavanje proizvodnje etanola u procesu fermentacije; mogućnosti primene imobilisanog kvasca u procesu fermentacije za dobijanje piva sa smanjenim sadržajem alkohola.

**Ključne reči:** niskoalkoholno pivo; bezalkoholno pivo; gnječenje; fermentacija; imobilisani kvasac

# SOME TECHNOLOGICAL APPROACHES TO THE PRODUCTION OF BEER WITH REDUCED ALCOHOL CONTENT

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Beer production is constantly evolving, with a number of new products appearing on the market, including reduced alcohol content beverages. The production of low-alcohol beer has various historical backgrounds. The reduced production of raw materials during the two world wars led to the production of wort with reduced initial extract and, therefore, production of beer with low alcohol content. In recent years, the EU has observed 50% increase in the production of beer with reduced alcohol content, and currently this segment of the beer market is within 4-5%. This is primarily due to the introduced restrictions regarding alcohol consumption and the search for new products in the competitive environment. Categorization of beer has been introduced in the EU, and low-alcohol beer is considered to contain no more than 1.2 % (v/v) ethanol. The object of the present work was the development of modified modes for beer production by applying biological approaches to the modification of methods and modes for mashing and fermentation. By analyzing the existing methods for the production of low-alcohol and non-alcohol beer, the following approaches have been proposed: methods and regimes for mashing to obtain wort with reduced extract; limiting the production of ethanol in the fermentation process; possibilities of applying immobilized yeast in the fermentation process to obtain beer with a reduced alcohol content.

**Key words:** low-alcohol beer; non-alcohol beer; mashing; fermentation; immobilized yeast

## IZAZOVI BIOFILMOVA U PIVARAMAMA

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Biofilmovi predstavljaju sveprisutan izazov u različitim industrijskim aplikacijama i okruženjima, ali predstavljaju jedinstvene rizike i komplikacije u pivaramama. S obzirom na preciznu prirodu pivarstva, uspostavljanje i postojanost biofilma može ugroziti integritet finalnog proizvoda, dovesti do neefikasnosti procesa, pa čak i rezultirati značajnim finansijskim gubicima. Ovaj esej pruža sveobuhvatnu diskusiju o formiranju biofilma u okruženju za proizvodnju piva, ispitujući mikrobiološke, fizičko-hemijske i operativne faktore koji doprinose njihovom razvoju. Nadalje, razgovaraćemo o savremenim strategijama za prevenciju i kontrolu, procenjujući njihovu efikasnost i implikacije na industriju. Biofilmovi, skupovi mikroorganizama zatvoreni u matrici ekstracelularnih polimernih supstanci (EPS), formiraju se na različitim površinama, uključujući nerđajući čelik, staklo i plastiku — materijale koji se obično koriste u infrastrukturi pivara. S obzirom na to da se proces proizvodnje piva oslanja na preciznu kontrolu mikrobnih populacija, upravo kvasca koji se koristi za fermentaciju, stvaranje neželjenih biofilma predstavlja značajnu opasnost. Mikroorganizmi koji su uobičajeno uključeni u formiranje biofilma u pivaramama pripadaju pretežno rodovima *Lactobacillus*, *Pediococcus* i *Acetobacter*. Ovi mikroorganizmi mogu da prijanjaju na površine i luče EPS, stvarajući kompleksne zajednice koje se odupiru standardnim procedurama čišćenja i sanitacije. Štaviše, polimikrobna priroda biofilma ih čini veoma prilagodljivim, olakšavajući preživljavanje u neoptimalnim uslovima kao što su niska dostupnost hranljivih materija i visoke koncentracije alkohola. Nekoliko fizičko-hemijskih faktora doprinosi formiranju biofilma u pivaramama, uključujući pH, temperaturu i dostupnost hranljivih materija. Nerđajući čelik, koji se široko koristi u pivaramama, generalno je otporan na koroziju, ali ipak može da obezbedi dovoljnu hrapavost površine za mikrobnu adheziju. Fizička svojstva okruženja u pivari, kao što su protok tečnosti i mehanička naprežanja, mogu dalje da modulišu formiranje biofilma. Operativni faktori kao što su procedure čišćenja, učestalost dezinfekcije i upotreba sredstava protiv kamenca mogu uticati na razvoj biofilma. Sistemi čišćenja na mestu (CIP), koji se obično koriste u pivaramama, mogu biti neadekvatni u potpunom uklanjanju uspostavljenih biofilma, što zahteva alternativne strategije za efikasno iskorenjivanje biofilma. Formiranje biofilma u pivaramama je složeno pitanje na koje utiču mnogi faktori. Rešavanje ovog izazova zahteva višestruki pristup koji integriše



mikrobiološka, fizičko-hemijska i operativna razmatranja. Trenutne strategije kontrole nude ograničenu efikasnost protiv robusnih, zrelih biofilma, naglašavajući potrebu za tekućim istraživanjem i tehnološkim inovacijama u ovoj kritičnoj oblasti.

**Ključne reči:** biofilm, pivarstvo, čišćenje, formiranje.

## BIOFILM CHALLENGES IN BREWERIES

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Biofilms present a ubiquitous challenge across various industrial applications and settings, but they pose unique risks and complications in breweries. Given the meticulous nature of brewing, the establishment and persistence of biofilms can compromise the integrity of the final product, lead to process inefficiencies, and even result in significant financial loss. This essay provides a comprehensive discussion on biofilm formation in brewing environments, examining the microbiological, physicochemical, and operational factors contributing to their development. Furthermore, we will discuss contemporary strategies for prevention and control, assessing their efficacy and implications for the industry. Biofilms, assemblages of microorganisms enclosed in a matrix of extracellular polymeric substances (EPS), form on various surfaces, including stainless steel, glass, and plastic—materials commonly used in brewery infrastructure. Given the reliance of the brewing process on the precise control of microbial populations, precisely the yeast used for fermentation, the establishment of unwanted biofilms constitutes a significant hazard. The microorganisms commonly implicated in brewery biofilm formation belong predominantly to the genera *Lactobacillus*, *Pediococcus*, and *Acetobacter*. These microorganisms can adhere to surfaces and secrete EPS, establishing complex communities that resist standard cleaning and sanitation procedures. Moreover, the polymicrobial nature of biofilms makes them highly adaptive, facilitating survival under suboptimal conditions such as low nutrient availability and high alcohol concentrations. Several physicochemical factors contribute to biofilm formation in breweries, including pH, temperature, and nutrient availability. Stainless steel, widely used in breweries, is generally resistant to corrosion but can still provide sufficient surface roughness for microbial adhesion. The physical properties of the brewery environment, such as fluid flow rates and mechanical stresses, can further modulate biofilm formation. Operational factors such as cleaning procedures, sanitization frequency, and the use of anti-scaling agents can influence biofilm development. Cleaning-in-place (CIP) systems, commonly used in breweries, can be inadequate in entirely removing established biofilms, necessitating alternative strategies for effective biofilm eradication. Biofilm formation in breweries is a complex issue influenced by many factors. Addressing this challenge requires a multifaceted approach integrating microbiological, physicochemical, and operational considerations. Current control strategies



offer limited effectiveness against robust, mature biofilms, underscoring the need for ongoing research and technological innovation in this critical area.

**Keywords:** Biofilm, Brewing, cleaning, formation.

# FT-IR TEHNOLOGIJA U ANALIZI PIVA-ŠTO MOŽEMO NAĆI?

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FT-IR tehnologija (infracrvena spektrofotometrija s Fourierovom transformacijom) je tehnika kojom se na vrlo jednostavan način može doći do velikog broja podataka o kemikalijama koje se mogu pronaći u raznim matriksima, pa tako i u pivu. Opsežne baze podataka mogu dati točne podudarnosti sa molekulama koje se nalaze u skeniranom uzorku. Uzorci (10) za analizu su bili internacionalni. Kod analize piva pakiranima u aluminijske limenke koristio se FT-IR (Spectrum 80 Two, PerkinElmer, Waltham, Massachusetts, USA) uređaj. Piva su prethodno filtrirana te se filter papir snimio na FT-IR uređaju. Dobiveni rezultati su bili opširni i uključivali su mnoge kemikalije, a najzanimljivije su bile one koje na prvi pogled nikako nisu povezane s pivom: legno di pioppo rosso - spettro uatr, frosch lemon balm (cleaning agent-for dishes), cillit antikalk (cleaning agent-for bathrooms), clozapine capsule.sp, nivea selftanning milk body milk, cucumber aloe mask (facial mask). U svakom slučaju, rezultati su zanimljivi i upućuju na to da se u pivovari tijekom kuhanja piva i pakiranja treba paziti na razne vanjske utjecaje (mirise) koji mogu završiti u pivu.

**Ključne reči:** FT-IR; pivo; limenke; kemikalije



# FT-IR TECHNOLOGY IN BEER ANALYSIS-WHAT CAN WE DETECT?

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FT-IR technology (infrared spectrophotometry with Fourier transformation) is a very simple technique that can be used to obtain a large number of data on chemicals that can be found in various matrices, including beer. Extensive databases can provide exact matches to the molecules found in the scanned sample. Ten international samples of canned beers were used in this analysis. An FT-IR (Spectrum 80 Two, PerkinElmer, Waltham, Massachusetts, USA) device was used for the analysis of beer packaged in aluminum cans. The beers were previously filtered and the filter paper was recorded on an FT-IR device. The obtained results were extensive and included many chemicals, and the most interesting were those that at first glance are not related to beer at all: legno di pioppo rosso - spectro uatr, frosch lemon balm (cleaning agent-for dishes), cillit antikalk (cleaning agent -for bathrooms), clozapine capsule.sp, nivea selftanning milk body milk, cucumber aloe mask (facial mask). In any case, the results are interesting and indicate that in the brewery, during the brewing and packaging of the beer, attention should be paid to various external influences (odors) that may end up in the beer.

**Key words:** FT-IR, beer; aluminum cans; chemicals

# PIVO KAO DEO BALASIRANE ISHRANE – ŠTA MOŽEMO SAZNATI IZ DEKLARACIJA NA AMBALAŽI

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Deklarisanje prehrambenih proizvoda (namirnica) ima za cilj da pruži potrošačima odgovarajuće informacije o toj namirnici, pri čemu informacije treba da budu tačne, jasne i lako razumljive potrošaču. Obavezne informacije na deklaraciji namirnica propisuje odgovarajuća zakonska regulativa, a uključuju, između ostalog, podatke o njenom sastavu, uključujući i sastojke koji mogu da izazovu alergije, zatim rok upotrebe, način čuvanja, naziv proizvođača, poreklo itd. Navođenje nutritivnog sastava proizvoda je obavezna informacija na deklaraciji prehrambenih proizvoda, a ima za cilj da potrošače informiše o energetske vrednosti proizvoda i količini hranljivih materija, uključujući sadržaj masti, ugljenih hidrata, proteina, soli i dijetnih vlakana. Iako navođenje nutritivnih podataka nije obavezno za alkoholna pića prema zakonskoj regulativi koja uređuje oblast deklarisanja hrane, pivarska industrija je odlučila da na dobrovoljnoj bazi navodi nutritivne informacije, uključujući i energetske vrednosti, na isti način kao i na deklaraciji hrane, predstavljene na 100 ml proizvoda. Pored nutritivnih informacija, na deklaraciji mogu biti prikazane i upozorenja u vezi sa ograničenjima u vezi konzumiranja piva, kao i broj standardnih pića po pakovanju. Navođenje i razumevanja pruženih informacija na deklaraciji piva omogućava potrošačima da razumeju nutritivni sastav piva, ali i doprinos konzumacije piva ukupnim energetske potrebama organizma, uzimajući u obzir kalorijsku vrednost alkohola koji na 1 g ima čak 7 kilokalorija. Takođe, informacije o ukupnoj energetske vrednosti, sadržaju ugljenih hidrata i šećera, mogu biti od koristi osobama na redukcionim dijetama ali imati i javnozdravstveni značaj, posebno u cilju podizanja svesti o doprinosu unosu alkohola ukupnom energetske unosu koji direktno korelira sa stepenom uhranjenosti i rizikom od razvoja gojaznosti.

## BEER AS A PART OF BALANCED DIET – WHAT WE CAN LEARN FROM FOOD LABELS

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Food labeling aims to provide consumers with adequate information about the food in question, and the information should be accurate, clear, and easy for consumers to understand. The mandatory information on the food label is determined by the respective legislation and includes, among other things, compositional information, including ingredients that may cause allergies, as well as the expiration date, method of storage, name of the manufacturer, origin, etc. The declaration of the nutritional composition of the product is a mandatory information on the declaration of food products and is intended to inform consumers about the energy value of the product and the amount of nutrients, including the content of fat, carbohydrates, protein, salt and fiber. Although providing nutrition information for alcoholic beverages is not mandatory under food declaration legislation, the brewing industry has decided to voluntarily provide nutrition information, including energy value, in the same manner as on the food declaration per 100 ml of product. In addition to nutritional information, the food label may also include warnings about beer consumption restrictions and the number of standard drinks per package. By providing and understanding the information on the beer label, consumers can understand the nutrient composition of beer and the contribution of beer consumption to the body's total energy needs, taking into account the caloric value of alcohol, which is up to 7 kilocalories per 1 gram. Information on total energy value, carbohydrate and sugar content can also be useful for people who need to follow a reduction diet. However, they are also important for public health, especially to raise awareness of the proportion of alcohol consumption in total energy intake, which directly correlates with the level of nutrition and the risk of developing obesity.

# UTICAJ AMBALAŽE NA STABILNOST I TRAJNOST PIVA (SA FOKUSOM NA PREDNOSTI I NEDOSTATKE STAKLENE I LIMENE AMBALAŽE)

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Pivo je alkoholni napitak koji nastaje alkoholnim vrenjem pivske sladovine. Iako ne spada u lako kvarljive namirnice, u toku skladištenja može doći do određenih promena u pivu. Uzrok tome mogu biti uslovi skladištenja i ambalaža koja se koristi. Pivo se puni u staklenu, limenu, plastičnu ambalažu i pivsku burad. Sve ove vrste ambalaže imaju svoje prednosti i mane i utiču zajedno sa uslovima čuvanja na stabilnost i trajnost piva. Poznato je da za čuvanje piva treba izbegavati mesta sa povišenom temperaturom i sa direktnim izvorom svetlosti. S toga, glavni cilj pivarske industrije nije samo da se proizvede kvalitetno pivo, već da mu se kvalitet održi tokom skladištenja, sve do trenutka njegove konzumacije.

Tokom skladištenja fizičko-hemijska, senzorna i mikrobiološka svojstva piva mogu biti izmenjena, pa pivo postaje manje atraktivno do tržišno neupotrebljivo. Cilj ovog rada je da se primenom različitih laboratorijskih metoda opišu promene fizičko-hemijskih i senzornih svojstava svetlog lager piva, uskladišteno tokom dva meseca u različitoj ambalaži, pri različitim uslovima. Veće promene su uočene kod boje i gorčine piva.

**Ključne reči:** pivo, ambalaže, skladištenje, fizičko-hemijska svojstva, senzorna svojstva

# IMPACT OF PACKAGING ON STABILITY AND DURABILITY OF BEER (WITH A FOCUS ON GLASS AND TIN PACKAGING)

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Beer is an alcoholic beverage that is produced by alcoholic fermentation of beer wort. Although it doesn't belong to easily perishable foodstuff, certain changes in the beer may occur during storage. The storage conditions and the packaging may be the cause of it. Beer is packaged in glass, metal and plastic packaging, and beer barrels. All these types of packaging have their advantages and disadvantages, and with storage conditions affects on the stability and durability of the beer. It is known that places with high temperature or a direct source of light should be avoided for storing beer. So, main goal for beer industry is not just to produce quality beer, but to maintain quality during storage, until the moment of its consummation.

Physico-chemical, sensory and microbiological properties of beer can be exposed to changes during storage, which makes beer less attractive to commercially unusable. The aim of this research was to use various laboratory methods to describe significant changes in the physical, chemical and sensory properties of light lager beers, produced in the brewery "Trebjesa", stored for two months in different packaging and under different conditions. Major changes were observed in color and bitterness of beer.

**Key words:** beer, packaging, storage, physico-chemical properties, sensory properties

# BAKTERIJE MLEČNE KISELINE - OSNOVA ZA PROIZVODNJU AUTOHTONIH SIREVA UPARENIH SA KRAFT PIVOM

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Autohtoni sirevi su bogatstvo i deo istorije svake zemlje. Najveći broj takvih sireva nosi ime mesta porekla gde su proizvedeni. Ovi proizvodi su svakako po obimu proizvodnje manje značajni, ali po kvalitetu još uvek mogu doprineti povećanju asortimana sireva svake zemlje. Specifičnost autohtonih sireva je posledica sastava bakterija mlečne kiseline (BMK) koje se nalaze u njima. BMK značajno doprinose nutritivnoj vrednosti proizvoda, kao što su ukus, miris, tekstura i druge. Mnoge od njih imaju i probiotička svojstva. Vrlo malo se zna o genetičkoj organizaciji BMK poreklom iz prirodnih staništa u kojima se sir proizvodi. Imajući u vidu značaj BMK u formiranju senzorskih karakteristika sireva je razlog zašto se u svetu proširuju istraživanja na karakterizaciji BMK izolovanih iz autohtonih sireva proizvedenih na tradicionalan način. Ta istraživanja podrazumevaju razvoj sredstava za genetičku analizu i manipulaciju ovih bakterija. Genetički i fiziološki okarakterisane BMK daju osnovu za formiranje kolekcije sojeva BMK koja se može koristiti za pripremu raznovrsnih starter kultura. Takva kolekcija BMK otvara mogućnost dobijanja autohtonih sireva visoke vrednosti sa deklaracijom određenog geografskog porekla. S druge strane, moguće je proizvoditi autohtone sireve uparene sa vinom ili pivom. Konzumiranje kraft (zanatskog) piva uparenog sa autohtonim sirom postaje veoma popularno poslednjih godina.

**Ključne reči:** bakterije mlečne kiseline, kolekcija sojeva, starter kulture, pivo

# LACTIC ACID BACTERIA - THE BASIS FOR THE PRODUCTION OF AUTOCHTHONOUS CHEESES PAIRED WITH KRAFT BEER

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Indigenous cheeses are wealth and a part of history of every country. Most of indigenous cheeses bear the name of the place of origin where they are produced. These products are certainly less significant in terms of production volume, but in terms of quality they can still contribute to increasing the assortment of cheeses of each country. The specificity of indigenous cheeses is in the composition of lactic acid bacteria (LAB). LAB contribute significantly to the nutritional value of products, such as taste, smell, texture, and others, while many of them also have probiotic properties. Very little is known about the genetic organization of LAB originating from the natural habitats in which cheese is produced. Bearing in mind the importance of LAB in the formation of sensory characteristics of cheeses is the reason why research on the characterization of BMKs isolated from the traditionally produced indigenous cheeses is expanding in the world. This research involves the development of means for genetic analysis and manipulation of these bacteria. Genetically and physiologically characterized LABs provide the basis for the formation of a collection of LAB strains that can be used to prepare a variety of starter cultures. Such a collection opens the possibility of obtaining indigenous cheeses of high value with a declaration of a certain geographical origin. Furthermore, it is possible to produce indigenous cheeses paired with wine or beer. The consumption of craft beer paired with artisanal cheese has become very popular in recent years.

**Keywords:** lactic acid bacteria, strain collection, starter culture, beer

# UPARAVANJE HRANE I PIVA: NOVI TREND I MOGUĆNOSTI

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Poslednjih godina globalno tržište piva postalo je promenljivije (npr. proizvodnja zanatskog piva), stvarajući nove mogućnosti za povećanje potrošnje piva. Danas potrošači piva traže neuobičajene senzorne karakteristike i imaju više hedonistički pristup stvarajući novi trend i inkorporirajući ga u kulturu piva. Preferencije potrošača su presudne za korišćenje i dalju proizvodnju piva i stvaranje lojalnih potrošača. Štaviše, ljubitelji piva i stručnjaci koji traže savršenu kombinaciju piva i hrane kako bi poboljšali uživanje u konzumiranju piva. Senzorne karakteristike piva imaju presudnu ulogu u odabiru jela, dominantni ukus piva se može opisati kao hmeljni, sladni, gorak, tamni i svetli. Osnovna pravila za usklađivanje hrane i piva u skladu sa kontrastom, dopunom ili osvežavajući. Prema literaturnim podacima, na teritoriji Srbije proizvodnja i potrošnja piva ima veoma dugu tradiciju, koju su u 5.-6. veku proizvodila slovenska i keltska plemena koja su se doselila. Za potrošače su sve važnija saznanja o senzornim karakteristikama i zanimljivosti o pivu, mnogi lokaliteti poznati po proizvodnji piva razvijaju turizam naglašavanjem ovog alkoholnog pića i organizovanjem raznih događaja na kojima posetioci mogu da uživaju u ispijanju piva. Mnoge manifestacije se organizuju da bi se povećala popularnost piva i mogu biti potencijalno mesto za primenu pravila uparavanja autentične srpske hrane i piva. Uzimajući sve u obzir, uparivanje piva i tradicionalne hrane može biti potencijalni pokretač razvoja pivskog turizma u Srbiji, jer pivski turizam zauzima značajno mesto u razvoju gastronomije i kulture ishrane i pića različitih zemalja.

**Ključne reči:** pivski turizam, uparavanje, tradicionalna hrana



# THE PAIRING FOOD AND BEER: NEW TREND AND POSSIBILITIES

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In recent years, the global beer market has shifted towards the production of craft beer, creating new possibilities for increasing beer consumption. Nowadays, beer consumers search for uncommon sensory characteristics and have a more hedonistic approach to beer, thereby creating a new trend in beer consumption culture. Consumer preferences are crucial for the use and further production of beer, as well as attracting loyal consumers. Furthermore, beer lovers and experts search for the perfect match of beer and food to improve the enjoyment of consuming beer. Sensory characteristics of beer have a crucial role in selecting food. The dominant flavor of beer can be described as hops, malt, bitter, dark, and light. Basic principles to match food and beer are according to contrast, complement or cleanse. According to literature, beer production and consumption has a very long tradition in Serbia, dating back to the 5<sup>th</sup>–6<sup>th</sup> century when beer was produced by Slavic and Celtic tribes that migrated into this region. The increasing interest of consumers in sensory characteristics and interesting information about beer influences many localities known for beer production, which are developing tourism by emphasizing this alcoholic drink and organizing various events where visitors can enjoy beer consumption. Many manifestations are organized to increase the popularity of beer and can be a potential place for implementing the rules for pairing authentic Serbian food and beer. Taking all into account, pairing beer and traditional food can be a potential driver for developing beer tourism in Serbia since it is well known that beer tourism occupies an important place in the development of gastronomy and food and beverage culture of different countries.

**Key words:** beer tourism, pairing, traditional food

# KRAFT SIR ZA KRAFT PIVO IZAZOV ZA PREDUZETNIŠTVO

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Proizvodnja autohtonih sireva ima veoma dugu tradiciju na Balkanskom području. Izučavanje svih aspekata njihove proizvodnje osigurava kontinuitet osigurava kontinuitet zanatskog načina proizvodnje. To bi omogućilo malim i srednjim proizvođačima mleka da se sve više usmere na proizvodnju sira sa oznakama geografskog porekla (zlatarski, sjenički, pirotski, homoljski, somborski i dr.). Tako probirljivi kupci dobijaju poruku predela zemlje, odnosno geografsko poreklo i po kojoj recepturi je sir proizveden. Probirljivom potrošaču, uz ukus i izgled, je to jedan od određujućih faktora za odluku o kupovoni. Pivarska industrija u Srbiji ostala je bez mnogih industrijskih pivara. Naprosto pregazilo ih je vreme i licencna proizvodnja stranih vrsta piva. Slično mlekarskoj industriji, ovaj biznis se oporavlja i donosi nove kvalitete kroz zanatske pivare (kraft beer). Najznačajnija razlika zanatskog i industrijskog piva je što se za zanatsko pivo koriste sirovine u izvornom obliku, a fermentacija i odležavanje se vrše na tradicionalana način. Šansa našeg malog i srednjeg preduzetništva u ovim proizvodnjama je u uparivanju proizvodnje autohtone sirarske proizvodnje i zanatskog piva. Time bi se dobila nova paleta proizvoda sa harmonijom ukusa i poboljšanju kvaliteta, čime bi se osvojila nova tržišta. Tako bi se mogli dobiti novi proizvodi, kao pivski sir, određene vrste sireva za određene vrste zanatskog piva i dr. To bi bili proizvodi sa novim senzornim karakteristikama ukusa, mirisa i kvaliteta koji traje (umami). Regionalni razvoj resursa za uparivanje autohtonih sireva, kraft piva i kreiranih čaša za pivo zahteva organizovano povezivanje zainteresovanih preduzetnika za ovaj razvoj. To podrazumeva i osnivanje Centra za dobijanje autohtonih sireva koji se mogu uparivati sa zanatskim vrstama piva. Ovakav zadatak podrazumeva organizovanu naučno-istraživačku i razvojnu aktivnost.

**Ključne reči:** Autohtoni sirevi, kraft pivo, pivski sir, ukus koji traje (umami)

# KRAFT CHEESE FOR KRAFT BEER A CHALLENGE FOR ENTREPRENEURSHIP

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The production of autochthonous cheeses has a very long tradition in the Balkan region. The study of all aspects of their production ensures the continuity of the artisanal way of production. This would enable small and medium-sized milk producers to increasingly focus on the production of cheese with designations of geographical origin (Zlatarski, Sjenica, Pirotski, Homolski, Somborski, etc.). In this way, discerning customers receive a message about the region of the country, that is, the geographical origin and according to which recipe the cheese was produced. For the discerning consumer, along with taste and appearance, it is one of the determining factors for the purchase decision. The brewing industry in Serbia was left without many industrial breweries. They were simply overtaken by time and license production of foreign types of beer. Similar to the dairy industry, this business is recovering and bringing new qualities through craft breweries (craft beer). The most significant difference between craft beer and industrial beer is that raw materials are used for craft beer in their original form, and fermentation and aging are done in a traditional way. The chance of our small and medium-sized entrepreneurship in these productions lies in pairing the production of autochthonous cheese production and craft beer. This would result in a new range of products with harmony of taste and improved quality, thereby conquering new markets. Thus, new products could be obtained, such as beer cheese, certain types of cheese for certain types of craft beer, etc. These would be products with new sensory characteristics of taste, smell and lasting quality (umami). The regional development of resources for the pairing of autochthonous cheeses, craft beer and created beer glasses requires an organized connection of interested entrepreneurs for this development. Such a task implies an organized scientific research and development activity.

**Key words:** Indigenous cheeses, kraft beer, beer cheese, lasting taste (umami)

# REGIONALNI RAZVOJ RESURSA ZA UPARIVANJE KRAFT SIREVA, KRAFT PIVA I KRAFT ČAŠA

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Gastronomija modernog doba, sa porastom standarda građana i velikim tehnološkim napretkom u pripremanju hrane, predstavlja drugačiju dimenziju čovečanstva. Sve je više kreativnosti i inovativnosti u tretiranju gastronomije ne samo kao sredstva za život, već i kao kulture, umetnosti i izvora velikog zadovoljstva. Nauka i struka je ušla u elaboriranje mnogih faktora koji doprinose ljudskom zadovoljstvu hranom i pićem. Jedna od oblasti je pripremanje jela i pića kroz koje se postiže ovo zadovoljstvo. Užitek dolazi od ukusa, mirisa i vizuelnog doživljaja uparenih jela i pića. U sklopu toga, danas postoji veliko interesovanje za uparivanje piva i sireva, nasuprot ustaljenom shvatanju ekskluzivnosti uparivanja vina i sireva. Tvrdi se da je pivo bolje od vina za uparivanje sa sirom zbog širokog spektra profila ukusa. Pivo karakteriše i gorčina i karbonizacija, što su specifične dimenzije ukusa za uparivanje sa sirevima. Proizvodnja kraft piva je oblast koja doživljava revolucionarni razvoj. Razvija se i kreiranje kraft čaša za pojedine vrste piva kako bi potpunije doživeli piće. U oblasti sirarstva razvoj se može ostvariti na osnovu istraživanja i selekcije bakterija mlečne kiseline koje utiču na nutritivnu vrednost sira. Na bazi ovih bakterija mogu se razviti različite vrste autohtonih sireva – kraft sireva koji su atraktivni za uparivanje sa kraf pivima. Regionalni razvoj resursa za uparivanje autohtonih sireva, kraft piva i kreiranih pivskih čaša zahteva organizovano povezivanje zainteresovanih za ovaj razvoj. To podrazumeva i osnivanje Centra za dobijanje autohtonih sireva. Ovakav zadatak zahteva organizovanu naučno-istraživačku i razvojnu delatnost.

**Ključne reči:** Regionalni razvoj, kraft pivo, kraf sir, kraft čaše

# REGIONAL RESOURCE DEVELOPMENT FOR PAIRING KRAFT CHEESE, CRAFT BEER AND KRAFT GLASSES

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Gastronomy of the modern age, with the rise of citizens' standards and great technological progress in food preparation, represents a different dimension of humanity. There is more and more creativity and innovation in treating gastronomy not only as a means of livelihood, but also as culture, art and a source of great pleasure. Science and profession have gone into elaborating the many factors that contribute to human satisfaction with food and drink. One of the areas is the preparation of food and drinks through which this pleasure is achieved. The pleasure comes from the taste, smell and visual experience of paired dishes and drinks. As part of that, today there is a great interest in the pairing of beer and cheese, contrary to the established understanding of the exclusivity of wine and cheese pairing. It is claimed that beer is better than wine for pairing with cheese due to its wide range of flavor profiles. Beer is characterized by both bitterness and carbonation, which are specific flavor dimensions for pairing with cheeses. Craft beer production is a field that is experiencing revolutionary development. The creation of kraft glasses for certain types of beer is also being developed in order to experience the drink more deep. In the area of cheesemaking, development can be achieved on the basis of research and selection of lactic acid bacteria that affect the nutritional value of cheese. On the basis of these bacteria, different types of autochthonous cheeses can be developed - craft cheeses that are attractive for pairing with craft beers. The regional development of resources for the pairing of indigenous cheeses, craft beer and created beer glasses requires an organized connection of those interested in this development. This includes the establishment of the Center for the production of autochthonous cheeses. Such a task requires organized scientific research and development activity.

**Keywords:** Regional development, craft beer, craft cheese, craft glasses.

# PIVO KAO NEMATERIJALNO KULTURNO NASLEĐE REPUBLIKE SRBIJE

Katarina Stojanović, Radovan Pejanović

Pivo je važan element nematerijalnog kulturnog nasleđa. Belgijsko pivo se našlo na UNESCO-voj listi svetske baštine, generišući na taj način i veću turističku potražnju zemlje. Pivo revitalizuje gradove i sela, lokalne ekonomije, fokusirajući se na proizvodnju i uvažavanje zanatskih i specijalnih piva. Proizvodnju zanatskog piva karakteriše proizvodnja manjeg obima u privatnim malim pivarama. Na osnovu pregleda literature i istorijskom metodom utvrđeno je da je pivo i deo kulturne prakse u cilju promovisanja međusobnog poštovanja drugih načina života, jer je pravljenje i poštovanje piva deo živog nasleđa niza zajednica širom sveta. Najnovija istraživanja ukazuju da pravljenje piva nije nužno rezultat poljoprivredne proizvodnje viškova, već je razvijeno u ritualne svrhe i duhovne potrebe, čak pre poljoprivrede. U kontekstu ovog rada, posmatramo ga kao drevni element kulture ishrane još od postanka čoveka i jedan od prvih napitaka koji su ljudi proizvodili i konzumirali. Cilj istraživanja je da ukaže na značaj formiranja našeg nacionalnog brenda piva Republike Srbije, koji bi takođe moglo naći mesto na listi nematerijane baštine, kao težnja za lokalnim, ne-korporativnim zanatskim načinom proizvodnje piva, formirajući kulturni narativ iz perspektive izgradnje zajednice, poslovanja, brendiranja destinacije i održivog razvoja. Proces velikih migracija iz ruralnih u urbana područja bi na taj način mogao biti usporen, sačuvano i revitalizovano nematerijano kulturno nasleđe Republike Srbije, kao i krajevi u kojima se proizvodnja odvija, pospešila bi se poljoprivreda i održala tradicionalna zanimanja.

**Ključne reči:** kultura ishrane; nematerijalno kulturno nasleđe; pivo; Republika Srbija; revitalizacija.

# BEER AS AN INTANGIBLE CULTURAL HERITAGE OF THE REPUBLIC OF SERBIA

Katarina Stojanović, Radovan Pejanović

Beer is an important element of intangible cultural heritage. Belgian beer was included in the UNESCO World Heritage List, thus generating a greater touristic demand. Beer production focused on the production and appreciation of craft and specialty beers revitalizes towns and villages, and local economies. Craft beer production is characterized by small-scale production in small, private breweries. Based on the literature and historical facts it was determined that beer is also a part of a cultural practice aimed at promoting mutual respect for others, because beer production and respect for beer is a part of heritage in a number of communities around the world. The latest research indicates that beer-making is not necessarily the result of agricultural use of surpluses, but was developed for ritual purposes and spiritual needs even before the start of agriculture. The paper considers it as an ancient element of food culture since the beginning of man and one of the first beverages that people produced and consumed. The goal of the study is to point out the importance of the establishment of national beer brands of the Republic of Serbia, which could find their place on the list of intangible heritage as an aspiration for a local, non-corporate artisanal way of beer production, and form a cultural narrative from the perspective of community building, business, branding destination and sustainable development. In this way, the process of migration from rural to urban areas could be slowed down, the intangible cultural heritage of the Republic of Serbia preserved and revitalized, as well as the preserving the areas where production takes place. Agriculture would thus be improved and traditional occupations would be saved.

**Key words:** food culture; intangible cultural heritage, beer, Republic of Serbia, revitalization.

# **SORTIMENT ZA DANAŠNJE POTREBE INDUSTRIJE SLADA I PIVA**

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Sorte dvoredog pivskog ječma se u Institutu za ratarstvo i povrtarstvo u Novom Sadu stvaraju u kontinuitetu više od 70 godina. Tokom dugogodišnjeg rada na selekciji i oplemenjivanju cilj je bio razvoj novih sorti sa poboljšanim karakteristikama koje će obezbediti visok potencijal za prinos i zadovoljiti kriterijume kvaliteta za industriju slada. Cilj ovoga rada bio je da se ispituju sorte dvoredog ječma stvorene u Institutu za ratarstvo i povrtarstvo i registrovane u poslednjih pet godina i 4 sorte stranih kompanija koje se nalaze u komercijalnoj proizvodnji u Srbiji za potrebe industrije slada. Genotipovi su imali dvorede i šestorede tipove klasa i pripadali su ozimim i jarim formama. Ispitivano je 9 sorti ječma u 2019/20. godini i 10 sorti u 2020/21. godini na 3 lokaliteta: Rimski šančevi, Sombor i Kikinda. Ogled je postavljen po slučajnom blok dizajnu na 10 m<sup>2</sup> u četiri ponavljanja uz primenu standardne agrotehnike. Tokom vegetacionih sezona beleženi su sledeći parametri: klasanje, poleganje, prinos zrna i sadržaj proteina. Statistička analiza fenotipskih podataka urađena je u statističkom programu JASP (Version 0.17.3). Najranije je cvetala sorta pod rednim brojem 8 u 2019/20. na lokalitetu Sombor (115 dan od početka godine), dok je ista sorta na lokalitetu Kikinda u 2020/21. godini klasala najkasnije (148 dan). Poleganje je uočeno samo na lokalitetu Rimski šančevi tokom 2019/20. godine kod stranih sorti sa maksimalnim poleganjem od 60%, i kod jedne jare sorte iz Instituta za ratarstvo i povrtarstvo, sa 30% poleganja. Prinos zrna varirao je od 2,240 kg/ha<sup>-1</sup> kod sorte 7 na lokalitetu Kikinda u 2020/21. godini, do 14,760 kg/ha<sup>-1</sup> kod sorte 4 na Rimskim šančevima u 2019/20. U drugoj ispitivanoj godini utvrđen je najveći sadržaj proteina kod sorte 8 u Somboru (13,5%), dok je u istoj godini sorta 2 u Kikindi imala sadržaj proteina od svega 8,2%. Iako je ispitivan relativno mali broj sorti i osobina, uočen je visok stepen diverziteta, što predstavlja odličnu osnovu za odabir najpogodnijeg sortimenta za potrebe industrije slada i pivarske industrije. Sve veći zahtevi industrije i tržišta omogućiće i značajnije učešće domaćeg sortimenta što bi svakako predstavljalo korak unapred kako za velika industrijska postrojenja tako i za potrebe malih zanatskih pivara čija težnja je usmerena ka izvrsnosti, novim izazovima i posebnosti u proizvodnji piva.



**Ključne reči:** oplemenjivanje ječma, sorte, raznovrsnost, industrija slada, zanatske pivare

**Zahvalnica:** Rad je deo projekta finansiran od strane Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije, evidencioni broj: 451-03-47/2023-01/200032

# MODERN BARLEY VARIETIES MEETING THE DEMANDS OF THE MALT AND BEER INDUSTRY

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The breeding of varieties of two-row barley has been continuously applied at the Institute of Field and Vegetable Crops in Novi Sad for more than 70 years. The goal during these years of research and improvement was to develop new varieties with enhanced traits to achieve maximum yields and meet quality standards for the malt industry. The study examined two-row barley varieties created at the Institute and registered in the past five years, along with four varieties from foreign companies used in commercial production in Serbia for the malt industry. The genotypes varied in spike types, including two-row and six-row, and belonged to either winter or spring forms depending on the sowing time. The research involved testing nine barley varieties in the 2019/20 season and ten varieties in the 2020/21 season at three different locations: Rimski šančevi, Kikinda, and Sombor. The trial was conducted using a randomized block design with 10 m<sup>2</sup> plots and four replications, employing standard agronomic practices. Various parameters were recorded during the growing seasons, such as heading, lodging, grain yield, protein content, and the percentage of class I grains. Statistical analysis of phenotypic data, including descriptive statistics and analysis of variance, was performed using the JASP statistical program. The variety numbered 8 in the 2019/20 season in Sombor (115 days from the beginning of the year) flowered earliest, while the same variety in Kikinda in the 2020/21 season headed latest (148 days). Lodging was observed only at the Rimski šančevi location during the 2019/20 season, with foreign varieties showing maximum lodging of 60%, and one spring variety from the Institute of Field and Vegetable Crops with 30% lodging. Grain yield ranged from 2,240 kg/ha-1 for variety 7 in Kikinda in the 2020/21 season to 14,760 kg/ha-1 for variety 4 at Rimski šančevi. In the second year of testing, the highest protein content was determined for variety 8 in Sombor (13.5%), while in the same year, variety 2 in Kikinda had a protein content of only 8.2%. Although a relatively small number of varieties and traits were tested, the study revealed significant diversity among the tested varieties, providing a strong foundation for selecting the most suitable varieties for the malt and brewing industry. The increasing demands of the industry and the market are expected to facilitate a more significant role for domestic varieties, representing a significant advancement for both large industrial



facilities and the needs of small craft breweries striving for excellence and uniqueness in beer production.

**Key words:** barley breeding, varieties, diversity, malt industry, craft breweries

**Acknowledgments:** „This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, grant number: 451-03-47/2023-01/200032“

# GOLOZRNI JEČAM KAO PRIRODAN IZVOR BIOAKTIVNIH SPOJEVA

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Ječam (*Hordeum vulgare* L.) je uz kukuruz, rižu i pšenicu jedna od najraširenijih kultura u proizvodnji tradicionalnih žitarica u svijetu. Odlikuje se izuzetnom prilagodljivošću različitim uvjetima uzgoja, od viših nadmorskih visina do sušnih i polusušnih uvjeta. Uzgaja se u tri osnovne svrhe: za ishranu stoke, kao polazna sirovina u proizvodnji slada za potrebe industrije piva i kao hrana za ljude. Ovisno o tome hoće li se proizvoditi za stočnu hranu, ili za prehranu ljudi, uključujući slad i prehrambene proizvode, ječam mora imati određene karakteristike i udovoljiti zahtjevima za pojedinu namjenu, od građe zrna do udjela bjelančevina i beta-glukana. Tipični kultivari ječma imaju sraslu pljevicu u stadiju pune zrelosti, i to nazivamo pljevičastom građom zrna, dok kod druge skupine manjeg broja kultivara dolazi do lakog odvajanja pljevice prilikom vršidbe i takav oblik nazivamo golozrnim ječmom. Općenito, pljevičasti ječam se koristi za proizvodnju slada jer u procesu slađenja pljevica štiti rast akrospire (klice slada) i osigurava prirodnu filtraciju tijekom postupka komljenja. Stoga se ječam smatra optimalnom sirovinom za proizvodnju slada, ali isto tako je i nutritivno vrijedna prehrambena namirnica. U zadnje vrijeme naglašen je interes za proučavanjem golozrnog ječma i njegove primjene u ljudskoj prehrani, upravo zahvaljujući zrnju oslobođenom od pljevice, većoj probavljivosti i mogućnostima olakšane prerade u prehrambene proizvode. Također, zrno golozrnog ječma bogato je prehrambenim vlaknima, posebno beta-glukanima, izdašnom količinom bjelančevina i različitim fenolnim spojevima. U ovom radu bit će prezentirani rezultati karakterizacije golozrnog ječma iz oplemenjivačkog programa Poljoprivrednog instituta Osijek, mogućnosti njegove namjenske upotrebe u proizvodnji brašna i slada s tehnološkog aspekta, te analize kemijskog sastava dobivenih frakcija brašna s naglaskom na sastav i raspodijeljenost biološki aktivnih komponenti.

**Ključne reči:** golozrni ječam, beta-glukani, fenolni spojevi, brašno, slad

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# HULLESS BARLEY AS A NATURAL SOURCE OF BIOACTIVE COMPOUNDS

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In addition to corn, rice and wheat, barley (*Hordeum vulgare* L.) is one of the most widespread crops in global production of traditional cereals. It is characterized by exceptional adaptability to different growing conditions, from higher altitudes to arid and semi-arid conditions. It is grown for three basic purposes: for feeding livestock, as a raw material in the production of malt for beer industry, and as food for humans. Depending on whether it is produced for animal feed or human consumption, including malt and food products, barley must have certain characteristics and meet the requirements of a particular purpose, from the grain structure to the protein and beta-glucan content. Typical barley cultivars have an adherent outer coat or hull, enclosing the caryopsis in the stage of full maturity, and it is called hulled grain structure. In another smaller group of cultivars, the hull easily separates during threshing, and we call this form hulless barley. In general, hulled barley is used for the production of malt because, the hull protects the growth of acrospires (malt sprouts) during the malting process and provides for a natural filtration during the mashing process. Therefore, barley is considered the optimal raw material for the production of malt, but it is also a nutritionally valuable foodstuff. Recently interest has risen in the study of hulless barley and its application in human nutrition, thanks to the grain freed from the hull, greater digestibility, and the possibility of easier processing into food products. Also, the grain of hulless barley is rich in dietary fiber, especially beta-glucans, and has a generous amount of proteins and various phenolic compounds. This paper will present the results of the characterization of hulless barley from the breeding program of the Agricultural Institute Osijek, the possibility of its intended use in the production of flour and malt from a technological aspect, and the analysis of chemical composition of the obtained flour fractions, with an emphasis on the composition and distribution of the biologically active components.

**Key words:** hulless barley, beta-glucans, phenolic compounds, flour, malt

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## INOVATIVNI TREND U BANJSKOM TURIZMU: PIVSKI SPA

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Uživanje u pivskim kupkama, postalo je trend u banjskom turizmu. Topla pivska kupka blagotvorno deluje na ljudski organizam. To je zato što pivski kvasac obiluje vitaminom B koji pomaže kod regenerisanja kože, a takođe je dobar u borbi protiv anksioznosti i depresije, pa ovakve kupke smanjuju stres i povećavaju raspoloženje. Kao primer dobre prakse u istraživanju, uzete su terme Laško u Sloveniji koje upravo nude jedinstveni "pivski spa" doživljaj svojim posetiocima. Ispitano je 87 ispitanika koji su preko turističke agencije Filip travel otišli u hotel Thermana Park Laško i tamo uživali u kupkama od meda i piva. U radu se želi predstaviti jedinstvenu inovativnu turističku ponudu koju je lako primeniti i na određene banje u Srbiji, sa ciljem povećanja posete kao i produženja boravka turista u banjama.

**Ključne reči:** banjski turizam, zdravlje, pivski turizam

## INNOVATIVE TREND IN SPA TOURISM: BEER SPA

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Enjoying beer baths has become a trend in spa tourism. A warm beer bath has a beneficial effect on the human body. That's because brewer's yeast is rich in vitamin B, which helps with skin regeneration, and is also good for fighting anxiety and depression, so these baths reduce stress and boost mood. As an example of good practice in our research, we took the spas of Laško in Slovenia, which offer their visitors a unique "beer spa" experience. 87 respondents who went to the hotel Thermana Park Laško through the travel agency Filip travel and enjoyed honey and beer baths there. In this paper, we wanted to present a unique, innovative tourist offer that can easily be applied to certain spas in Serbia, with the aim of increasing visits and prolonging the stay of tourists in spas.

**Key words:** Spa, health, beer tourism



# POTROŠNJA PIVA U SLOVAČKOJ

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Slovaci su tradicionalno veliki ljubitelji piva. Svaki Slovak popije u proseku oko 140 krigli piva godišnje, što je oko 70 litara po glavi stanovnika. Što se tiče potrošnje piva u Slovačkoj u 2022 godine dolazi do pada zbog povećanja cena, inflacije i promenjenim navikama potrošača. Kao rezultat smanjenja potrošnje, možemo smatrati sve popularnijem bezalkoholnim pivima i radlerima. Slovačka tako održava najviše rangove u okviru Evropske unije po popularnosti bezalkoholnog piva. Svake godine se na tržištu pojavljuju nove vrste piva, koje imaju za cilj privlačenje sve više novih korisnika ili kupaca. U Slovačkoj imamo 4 velike pivare i 72 zanatske ili kraft pivare. Cilj ovog rada je da prikaže trenutnu situaciju u pivarskoj industriji na teritoriji Republike Slovačke.

**Ključne reči:** pivo, pivarska industrija, tržište.

## BEER CONSUMPTION IN SLOVAKIA

Branislav Dudić

Slovaks are big fans of beer. Every Slovak drinks an average of 140 pints of beer per year, which is about 70 liters per capita. As for beer consumption in Slovakia in 2022, there will be a decline due to the price increases, inflation and changed consumer habits. As a result of the decrease in consumption, we can consider non-alcoholic beers and radlers increasingly popular. Every year, new types of beer appear on the market, which aim to attract more and more new users or customers. In Slovakia, we have 4 large breweries and 72 craft or craft breweries. The aim of this work is to present the current situation in the brewing industry on the territory of the Slovak Republic.

**Keywords:** beer, brewing industry, market.

# ULOGA VEŠTAČKE INTELIGENCIJE U KREIRANJU KRAFT PIVA

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Integracija veštačke inteligencije u industriju craft piva predstavlja jedinstven i inovativan pristup koji ima potencijal da revolucionizuje proces proizvodnje piva. Ovaj naučni rad istražuje "Ulogu veštačke inteligencije u kreiranju craft piva" i dublje analizira različite primene i implikacije veštačke inteligencije u proizvodnji, kontroli kvaliteta i tržišnoj promociji craft piva. Rad počinje ispitivanjem automatizacije procesa proizvodnje piva putem veštačke inteligencije, ističući prednosti analize i kontrole podataka u realnom vremenu. Takođe istražuje kako veštačke inteligencije doprinosi profilisanju ukusa i kontroli kvaliteta craft piva, obezbeđujući doslednost u ukusu, aromi i izgledu. Takođe se analizira primena veštačke inteligencije u generisanju recepata, prikazujući njenu sposobnost da kreira nove, jedinstvene i prilagođene recepte za pivo analizirajući obimne podatke i istorijske informacije o proizvodnji piva. Osim toga, rad istražuje ulogu veštačke inteligencije u optimizaciji lanca snabdevanja craft piva, od nabavke sastojaka do distribucije, što dovodi do ušteda i unapređenja održivosti. Pruža uvid u analizu tržišta i preferencije potrošača, nudeći proizvođačima craft piva mogućnost donošenja odluka zasnovanih na podacima u vezi sa proizvodnjom i strategijama marketinga piva. Osvrće se na izazove i ograničenja veštačke inteligencije u proizvodnji craft piva, uključujući probleme sa kvalitetom podataka i zabrinutosti u vezi sa potencijalnim gubitkom tradicionalnog zanatstva. Pored toga, rad istražuje stvarne studije slučaja craft pivara koje su uspešno implementirale veštačke inteligencije u svoje procese proizvodnje piva, prikazujući praktične koristi i rezultate ove tehnologije. Takođe se razmatraju etički i regulatorni aspekti, fokusirajući se na pitanja gubitka radnih mesta, privatnosti i usklađenosti sa postojećim regulativama u industriji. Rad zaključuje spekulacijama o budućim trendovima u integraciji veštačke inteligencije u proizvodnji craft piva i kako se tehnologija može nastaviti razvijati, unoseći nove inovacije u industriju proizvodnje piva. Ovo naučno istraživanje o interakciji između veštačke inteligencije i craft piva ne samo da baca svetlo na transformacioni potencijal tehnologije unutar drevnog zanata, već pruža okvir za razumevanje mogućnosti, izazova i etičkih razmatranja veštačke inteligencije u industriji proizvodnje piva. Nudi dragocene uvide proizvođačima piva, istraživačima i donosiocima odluka koji traže da se snađu u dinamičnom okruženju veštačke inteligencije u proizvodnji craft piva.

**Ključne reči:** Veštačka inteligencija, craft pivo, zadovoljstvo potrošača, optimizacija lanca snabdevanja



## THE ROLE OF AI IN CREATING CRAFT BEER

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The integration of Artificial Intelligence (AI) into the craft beer industry represents a unique and innovative approach that has the potential to revolutionize the brewing process. This scientific paper explores "The Role of AI in Creating Craft Beer" and delves into the various applications and implications of AI in the production, quality control, and marketability of craft beer. The paper investigates AI's role in optimizing the craft beer supply chain, from ingredient sourcing to distribution, leading to cost savings and enhanced sustainability. It provides insights into market analysis and consumer preferences, offering craft brewers the ability to make data-driven decisions regarding beer production and marketing strategies. The challenges and limitations of AI in craft beer production are also addressed, including data quality issues and concerns related to the potential erosion of traditional craftsmanship. Furthermore, the paper explores real-world case studies of craft breweries successfully implementing AI in their brewing processes, demonstrating the practical benefits and outcomes of this technology. Ethical and regulatory considerations are examined, with a focus on job displacement, privacy, and compliance with the existing industry regulations. The paper concludes by speculating on future trends in the integration of AI in craft beer production and how it may continue to evolve, ushering in new innovations within the brewing industry. This scientific exploration of the intersection between AI and craft beer not only sheds light on the transformative potential of technology within an age-old craft but also provides a framework for understanding the opportunities, challenges, and ethical considerations of AI in the brewing industry. It offers valuable insights for brewers, researchers, and policymakers seeking to navigate the dynamic landscape of AI in craft beer production.

**Key words:** Artificial intelligence, craft beer, customer satisfaction, supply chain optimization

## MARKETING STRATEGIJE KRAFT PIVA

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Usled konstantnog organizacionog i tehnološkog rasta i razvoja, kao i sve zahtevnijeg tržišta potrošača, industrija kraft piva, poput drugih industrija, treba da usvoji savremene metode i tehnike menadžmenta kako bi obezbedila opstanak na lokalnim i globalnom tržištu. Marketing predstavlja jedan od ključnih koncepata poslovanja, a kombinacija tradicionalnih i savremenih marketinških strategija važan je faktor u opstanku i razvoju malih biznisa, naročito kada je u pitanju industrija kraft piva. Industrija kraft piva postaje sve razvijenija i poznatija na svetskim i lokalnim tržištima, a neizbežan deo tog razvoja su i sve složeniji zahtevi potrošača ovih specifičnih proizvoda. Kako bi kompanija pravilno odgovorila na specifične potrošačke zahteve, pored kvaliteta sirovina i proizvodnog procesa, potrebno je ulagati u efektivne marketinške strategije kako bi se ostvarila održiva konkurentska prednost.

**Ključne reči:** Kraft pivo, marketing strategije, biznis

## CRAFT BEER MARKETING STRATEGIES

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Due to constant organizational and technological development and growth, as well as the increasingly demanding consumer market, the craft beer industry, like other industries, should adopt an apply modern management methods and techniques to ensure survival in the local and global market. Marketing is one of the key business concepts, and the combination of traditional and modern marketing strategies is an important factor in the survival and development of the small businesses, especially when it comes to craft beer industry. The craft beer industry is becoming increasingly developed and well known on global and local markets, and an inevitable part of that development involves the increasingly complex demands of consumers of these specific products. In order for the company to be able to respond properly to the specific demands of consumers, in addition to the quality of the ingredients and production process, the company should invest in effective marketing strategies in order to achieve a sustainable competitive advantage.

**Key words:** Craft beer, marketing strategies, business



