III. FIB CONFERENCE, 2022

3rd International Scientific and Professional Conference

FOOD INDUSTRY BY-PRODUCTS

ByProExtract - Application of innovative techniques of the extraction of bioactive components from by-products of plant origin

Stela Jokić

Osijek, 29. 8. 2022.

The Conference is supported by Croatian Science Foundation under the project "Application of innovative techniques of the extraction of bioactive components from by-products of plant origin" (UIP-2017-05-9909).

ByProExtract

Application of innovative techniques of the extraction of bioactive components from by-products of plant origin"

(2018-2023)

Principal Investigator: : prof. dr. sc. Stela Jokić

(Budget: ***1.607.708,72 HRK****)*

ByProExtract Team

„Great things are never done by one person. They're done by a team of people."

- Steve Jobs

Everything starts with a good idea……

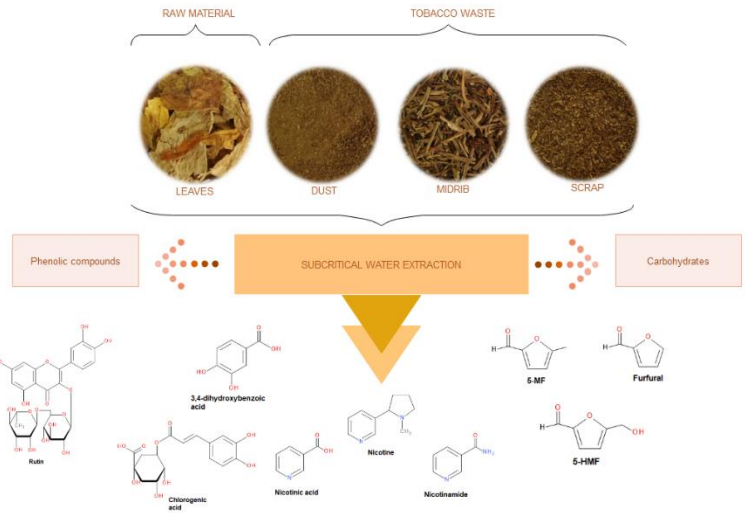
but also from raw material….

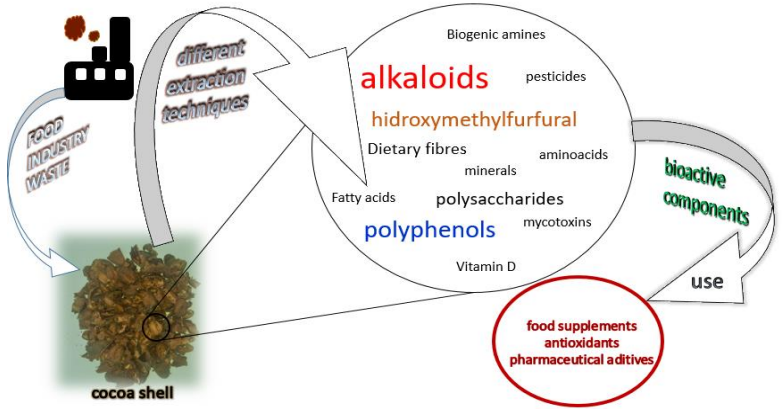
CITRUS PEEL

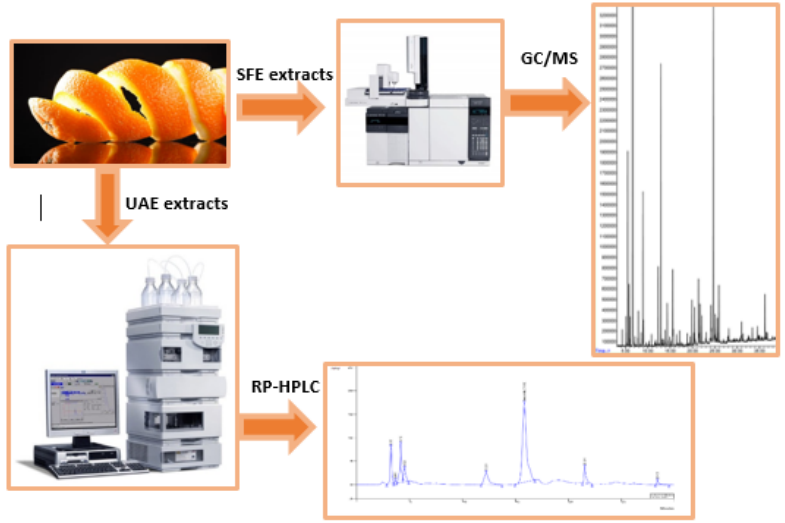
COCOA SHELL

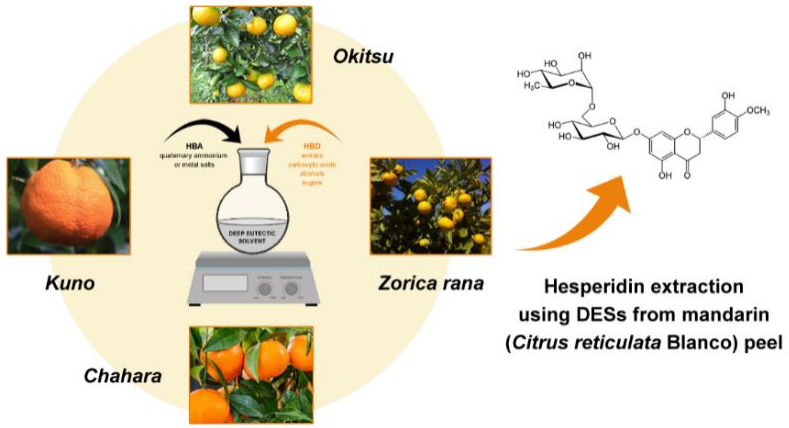
TOBBACO WASTE

INNOVATIVE EXTRACTION TECHNIQUES

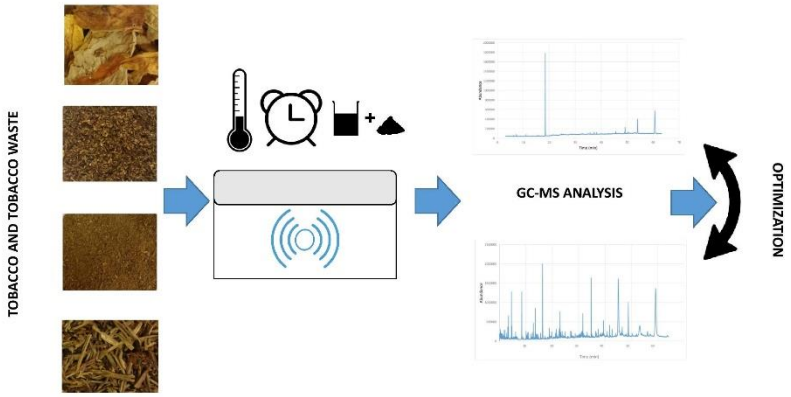


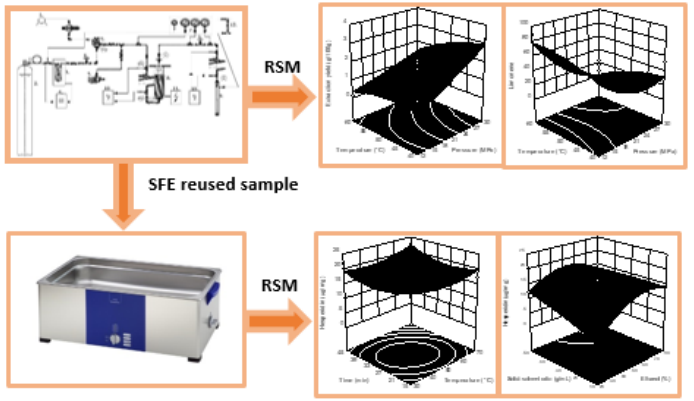






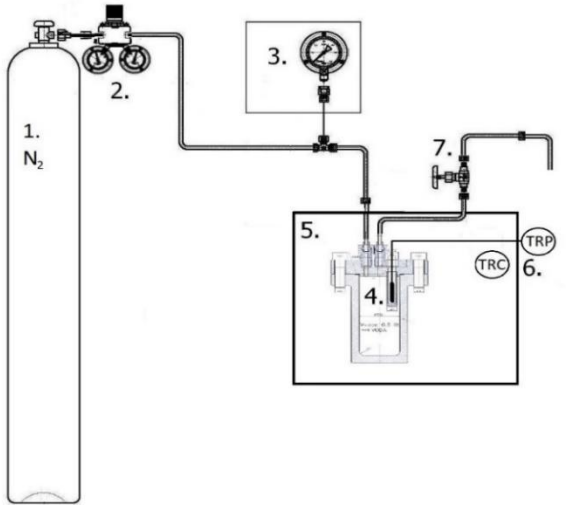
Hesperidin extraction using DESs from mandarin (*Citrus reticulata* Blanco) peel





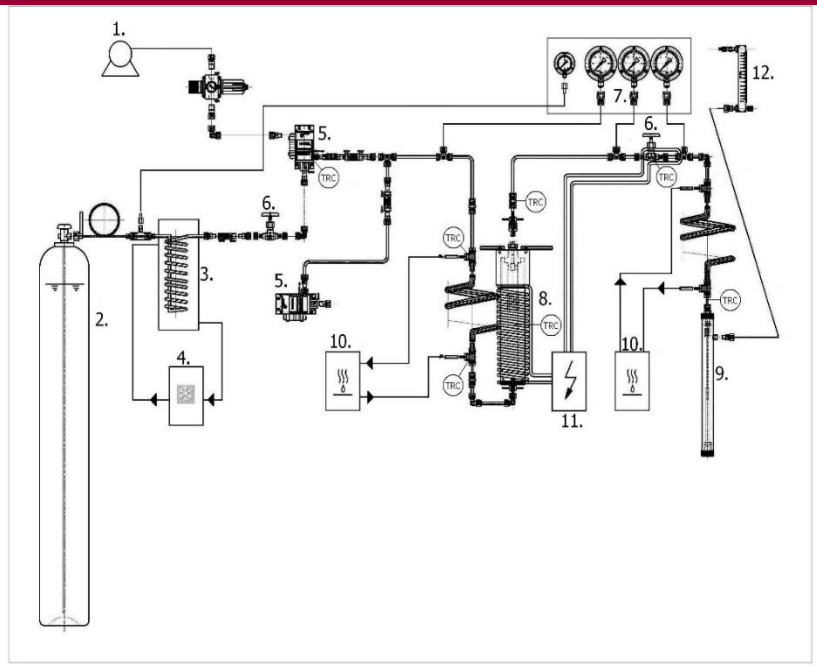
NEW EQUIPMENT

ULTRASOUND-ASSISTED EXTRACTION

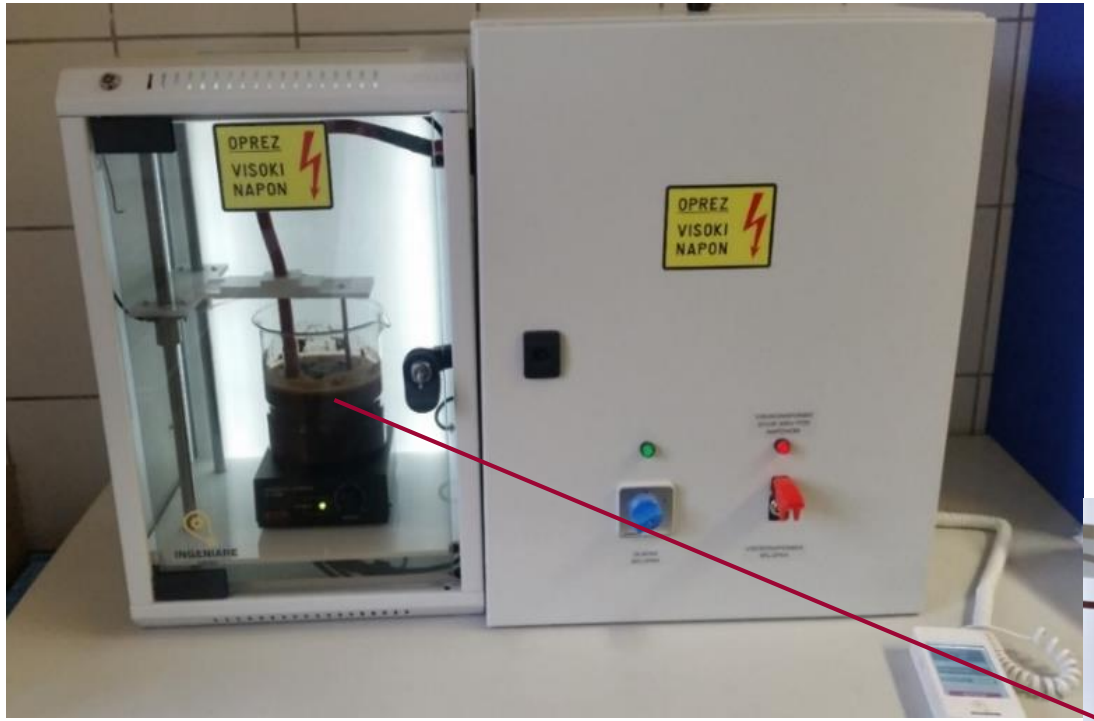


SUBCRITICAL WATER EXTRACTION

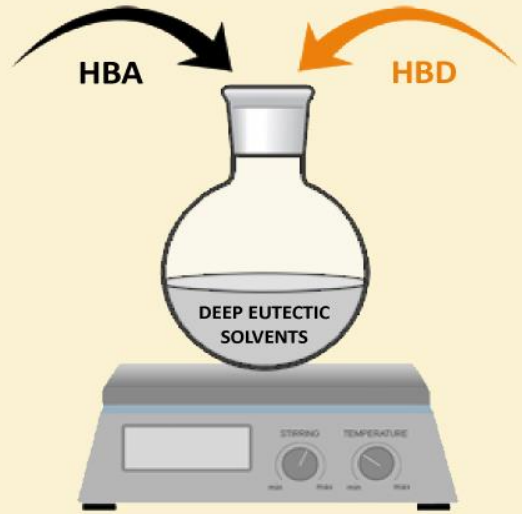
MICROWAVE-ASSISTED EXTRACTION



SUPERCRITICAL CO_2 EXTRACTION

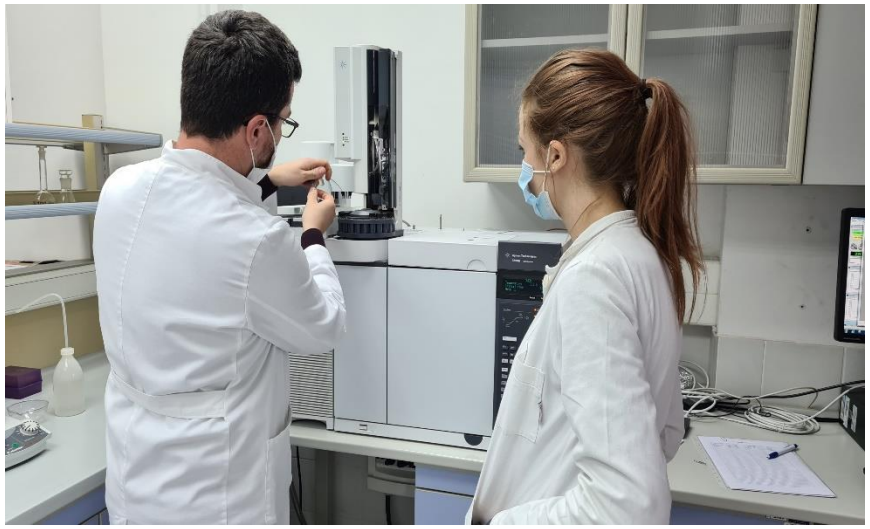


HIGH-VOLTAGE ELECTRIC DISCHARGE EXTRACTION

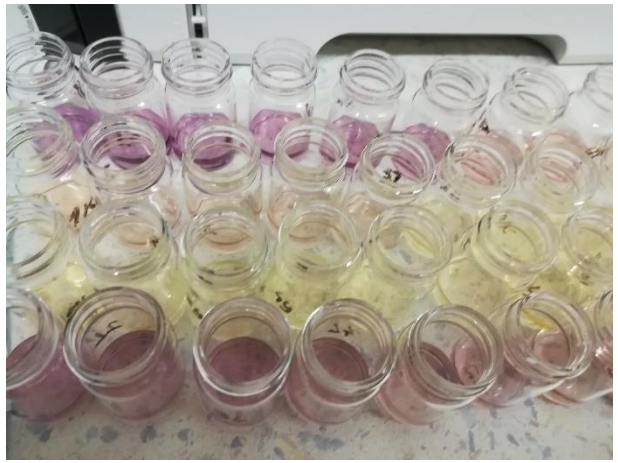


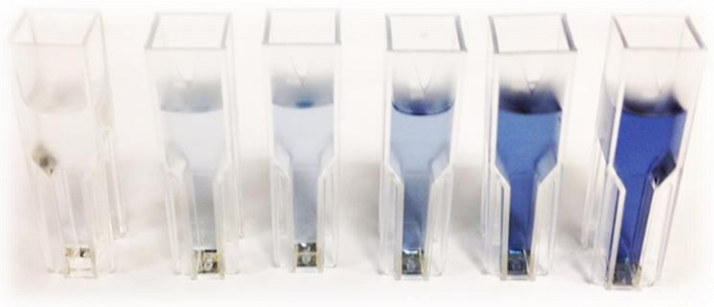
EXTRACTION USING DEEP EUTECTIC SOLVENTS (DES)

HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC)

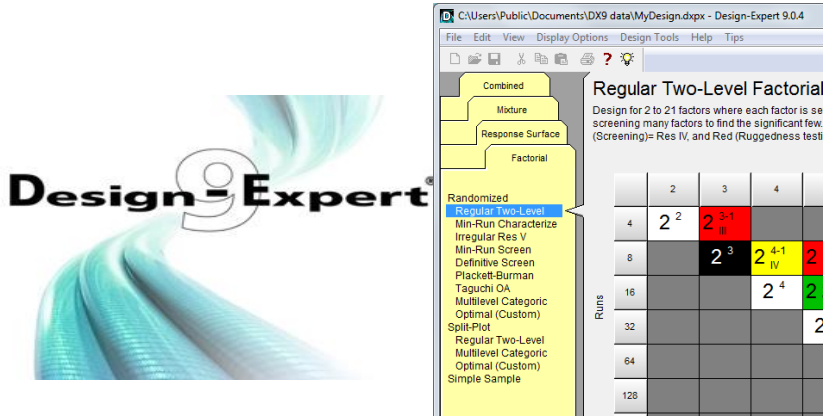


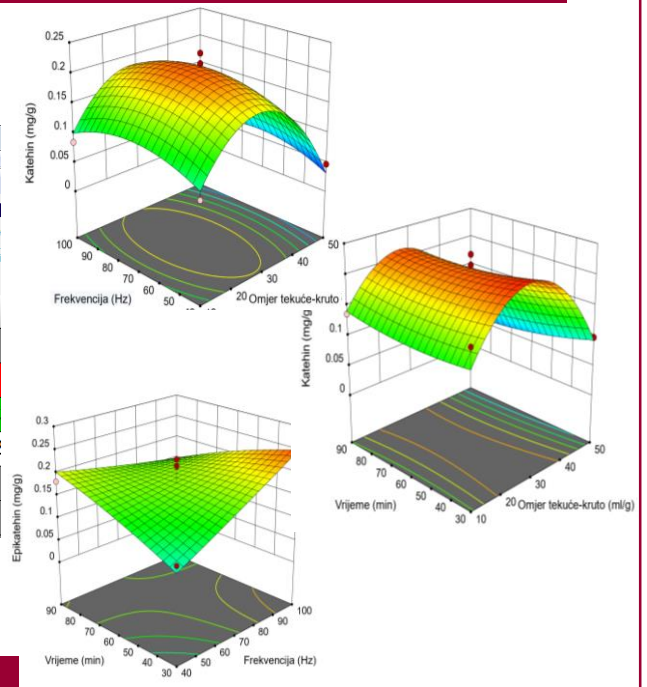
GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS)





SPECTROPHOTOMETRIC METHODS





OPTIMIZATION

SPRAY DRYING

FOOD REVIEWS INTERNATIONAL
https://doi.org/10.1080/87559129.2021.1938601

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Spray Drying as a Method of Choice for Obtaining High Quality Products from Food Wastes– A Review

Marija Banožić[a], Jelena Vladić[b], Ines Banjari[a], Darko Velić[a], Krunoslav Aladić[a], and Stela Jokić[a]

PROJECT RESULTS

33 JOURNAL PUBLICATIONS

50 CONFERENCES

7 BOOK CHAPTERS

3 DOCTORAL THESIS

FOOD REVIEWS INTERNATIONAL
https://doi.org/10.1080/87559129.2021.1938601

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COCOA

Nika

Kernel Cake

by Jelena Čakarević [1], Senka Vidović [1], Jelena Vladić [1], Aleksandra Gavarić, Stela Jokić [2,*], Nika Pavlović [3], Marijana Blažić [4] and Ljiljana Popovi

Plum oil cake protein isolate: a potential source of bioactive peptides

Jelena C. Čakarević[1], Senka S. Vidović[1], Jelena Z. Vladić[1], Stela D. Jokić[2], Nika S. Pavlović[3], Ljiljana M. Popović*[1]

S. Jokić* | Od industrijskog otpada do

Prehram
Sveučiliš

Sepa
peel
ultra
and

Stela Jokić, Maja Molnar, Ana-Marija Cikoš, Martina Jakovljević, Silvija Šafranko & Igor Jerković

Open Access Article

An Approach to Value Cocoa Bean By-Product Based on Subcritical Water Extraction and Spray Drying Using Different Carriers

by Stela Jokić [1,*], Nataša Nastić [2], Senka Vidović [2], Ivana Flanjak [1], Krunoslav Aladić [1] and Jelena Vladić [2,*]

Carbohydrates—Key Players in Tobacco Aroma Formation and Quality Determination

by Marija Banožić [1], Stela Jokić [1,*], Đurđica Ačkar [1], Marijana Blažić [2] and Drago Šubarić [1]

Recent advances in extraction of bioactive compounds from tobacco industrial waste-a review

Marija Banožić, Jurislav Babić, Stela Jokić

Green Extraction Methods for Active Compounds from Food Waste—Cocoa Bean Shell

by Nika Pavlović [1], Stela Jokić [2], Martina Jakovljević [2], Marijana Blažić [3] and Maja Molnar [2,*]

S. Jokić et al., High-Voltage Electric Discharge Extraction of Bioactive Compounds..., *Chem. Biochem. Eng. Q.*, **33** (2) 271–280 (2019) 271

High-Voltage Electric Discharge Extraction of Bioactive Compounds from the Cocoa Bean Shell+

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S. Jokić,[a,*] N. Pavlović,[b] A. Jozinović,[a] D. Ačkar,[a] J. Babić,[a] and D. Šubarić[a]

Subcritical Water Extraction Laboratory Plant Design and Application

Jokić[1], S., Aladić[2], K., Šubarić[1*], D.

Shell: A By-Product with Great Potential for Application

by Jelena Panak Balentić [1], Đurđica Ačkar [1,*], Stela Jokić [1], Antun Jozinović [1], Jurislav Babić [1], Borislav Miličević [1], Drago Šubarić [1] and Nika Pavlović [2]

Sustainable Green Procedure for Extraction of Hesperidin from Selected Croatian Mandarin Peels

by Stela Jokić [1], Silvija Šafranko [1,*], Martina Jakovljević [1], Filip Kolarević [1], Jurislav Babić [1] and Maja Molnar [1]

molecules

Article

Original scientific paper

Green extraction techniques of bioactive

NIKA PAVLOVIĆ*[1], MARTINA JAKOVLJEVIĆ[2], MAJA MIŠKULIN[1], MAJA MOLNAR[2], ĐURĐICA AČKAR[2], STELA JOKIĆ[2]

Optimization of Ultrasound-Assisted Extraction of Some Bioactive Compounds from Tobacco Waste

by Marija Banožić, Jurislav Babić and

Faculty of Food Technolog

* Author to whom corresp

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Volatile organic compounds of tobacco leaves *versus* waste (scrap, dust, and midrib): extraction and optimization

Marija Banožić, Krunoslav Aladić, Igor Jerković, Stela Jokić

European Journal of Lipid Science and Technology

Euro Fed Lipid

Research Article

Recovery of To

Supercritical Carbon Dioxide

Functions and Applications

Evie P. Hayden

Editor

Sveučilište Josipa Jurja Strossmayera u Osijeku Prehrambeno-tehnološki fakultet Osijek

Neke mogućnosti iskorištenja nusproizvoda prehrambene industrije

PTEFS

Innovat Processing od gies:

Poglavlje 2

PRIMJENA SUŠENJA RASPRŠIVANJEM U PROCESIRANJU NUSPROIZVODA PREHRAMBENE INDUSTRIJE

Marija Banožić[1], Krunoslav Aladić[1], Jelena Vladić[2], Stela Jokić[1]*

[1]*Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet Osijek, Franje Kuhača 18, 31000 Osijek, Hrvatska, *sjokic@ptfos.hr*

[2]*Univerzitet u Novom Sadu, Tehnološki fakultet Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Srbija*

Poglavlje 3

PRIMJENA EKSTRAKCIJE SUBKRITIČNOM VODOM U SVRHU VALORIZACIJE OTPADA I NUSPROIZVODA PREHRAMBENE INDUSTRIJE

Jelena Vladić[1]*, Senka Vidović[1], Stela Jokić[2]

[1]*Univerzitet u Novom Sadu, Tehnološki fakultet Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Srbija, *vladicjelena@gmail.com*

[2]*Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet Osijek, Franje Kuhača 18, 31000 Osijek, Hrvatska*

SAŽETAK

Otpad i nusproizvodi prehrambene industrije mogu predstavljati značajan izvor komponenti poput proteina, lipida, vitamina, minerala, vlakana i polifenola. Njihovim racionalnim iskorištenjem smanjuje se negativan utjecaj na okoliš jer se smanjuje odlaganje otpada i njegova degradacija u okolišu, a dodatno se osigurava povoljna sirovina za proizvodnju različitih vrijednih proizvoda. Racionalnija upotreba prirodnih resursa i uvođenje zelenih inovativnih postupaka u proizvodnju mogu se pozitivno odraziti i na položaj prehrambene industrije na tržištu.

Ekstrakcija subkritičnom vodom razvijena je kao alternativni postupak ekstrakcije konvencionalnim tehnologijama i odlikuje ju primjena sigurnog otapala i selektivna ekstrakcija bioaktivnih komponenti. Budući da se ta metoda svrstava u učinkovite postupke valorizacije otpada i nusproizvoda prehrambene industrije, u ovom poglavlju bit će predstavljeni neki od primjera valorizacije nusproizvoda različitih prehrambenih industrija koje u svojim tehnološkim procesima generiraju značajne količine otpada.

Ključne riječi: subkritična voda, otpad i nusproizvodi, zelena ekstrakcija, alternativna otapala

RESULTS

foods

Article

Green Extraction Techniques for Obtaining Bioactive Compounds from Mandarin Peel (*Citrus unshiu* var. *Kuno*): Phytochemical Analysis and Process Optimization

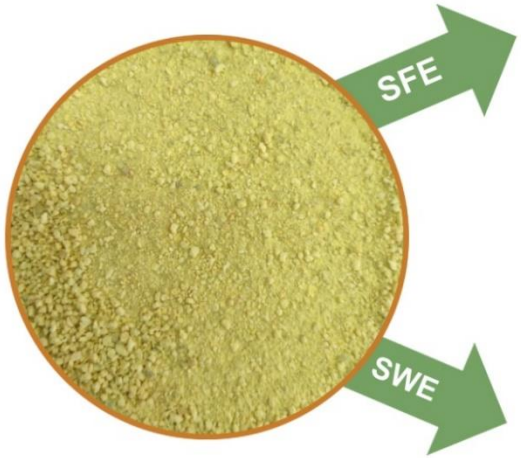
Silvija Šafranko [1], Ina Ćorković [1], Igor Jerković [2], Martina Jakovljević [1], Krunoslav Aladić [1], Drago Šubarić [1] and Stela Jokić [1,*]

Okitsu

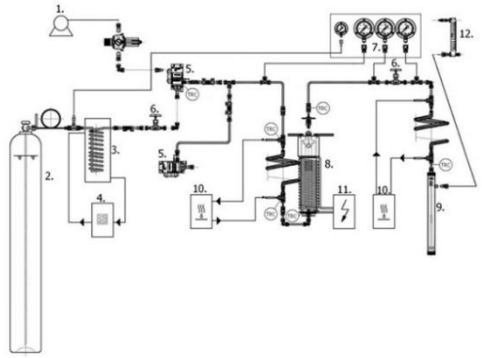
Kuno

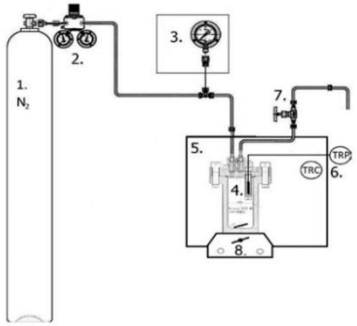
Chahara

Zorica rana

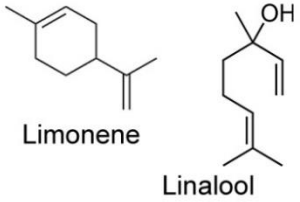


Mandarin peel
(*Citrus unshiu* var. *Kuno*)





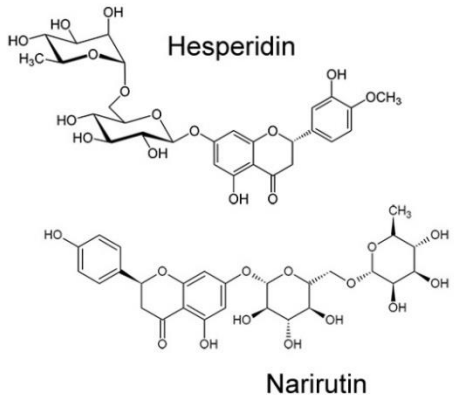
Volatile compounds

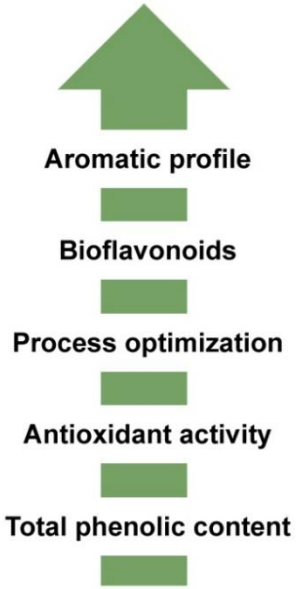


Limonene

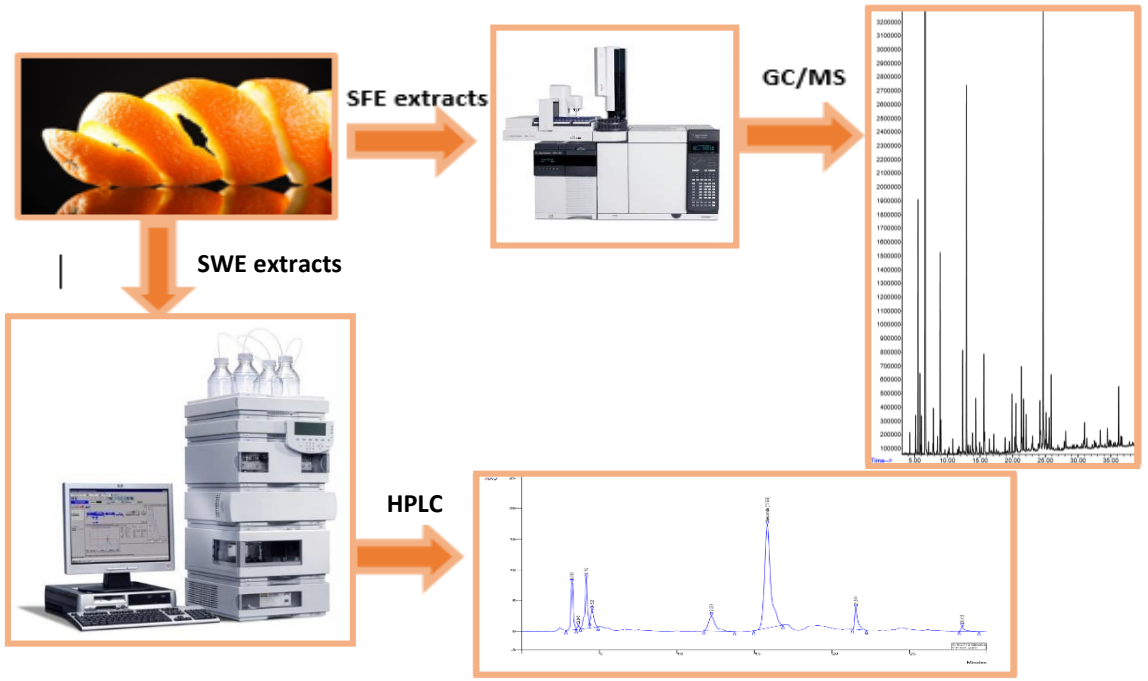
Linalool

Bioflavonoids





RESULTS



Compound	Rt	RI	Zorana		Kuno		Okica		Chanara	
			100 bar	300 bar	100 bar	300 bar	100 bar	300 bar	100 bar	300 bar
α-Thujene	4,082	932	-	-	0.1	0.1	-	-	-	-
α-Pinene	4,237	940	-	-	0.6	0.3	-	0.1	-	-
Sabinene	5,091	978	-	-	0.2	0.1	-	0.1	-	-
β-Pinene	5,191	982	0.1	-	0.4	0.3	0.1	0.1	-	-
β-Myrcene	5,478	992	0.6	0.4	2.3	1.9	0.5	1.0	0.1	0.1
Octanal	5,783	1003	-	-	0.1	0.1	0.1	0.1	-	-
Phellandrene	5,876	1007	-	-	0.1	0.1	-	-	-	-
p-Cymene	6,440	1028	1.2	1.1	0.1	0.1	0.5	0.9	0.3	0.1
Limonene	6,602	1034	37.2	35.1	66.8	66.6	35.4	52.8	11.7	3.5
trans-β-Ocymene	7,110	1051	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
γ-Terpinene	7,467	1062	3.9	4.4	8.4	8.5	5.0	6.6	1.3	1.0
cis-Sabinene hydrate	7,755	1071	0.1	0.1	0.1	0.1	0.1	0.1	-	-
α-Terpinolene	8,437	1089	0.4	0.4	0.6	0.6	0.4	0.6	0.2	0.1
Linalool	8,855	1100	3.4	4.3	1.6	1.7	3.0	2.6	4.3	2.2
Nonanal	8,891	1101	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Citronellal	10,793	1155	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Terpinen-4-ol	11,744	1179	0.2	0.3	0.1	0.1	0.2	0.2	0.3	0.2
α-Terpineol	12,286	1191	1.4	1.6	0.6	0.6	1.2	0.9	2.0	2.2
Decanal	12,864	1204	0.6	0.7	0.4	0.4	0.6	0.4	0.8	0.6
trans-Carveol	13,405	1219	-	-	-	-	0.1	-	-	-
Citronellol	13,809	1230	0.3	0.3	0.1	0.1	0.2	0.1	0.2	0.1
(Z)-Citral	14,283	1242	-	-	0.1	0.1	-	-	-	-
(E)-Citral	15,511	1271	-	-	0.1	0.1	-	-	-	-
Thymol	16,609	1295	0.2	0.4	-	-	-	0.3	-	-
Carvacrol	16,992	1304	0.7	0.9	0.1	0.1	0.1	0.1	0.4	0.6
Undecanal	17,023	1305	-	-	0.1	-	0.1	-	-	-
δ-Elemene	18,253	1337	0.5	0.5	0.2	0.2	0.5	0.3	0.8	0.6
Citronellyl acetate	18,982	1354	-	-	-	-	0.2	0.2	0.3	0.1
Neryl acetate	19,452	1365	0.4	0.4	0.1	0.1	0.2	0.2	0.4	0.4
α-Copaene	19,881	1375	1.3	1.4	0.5	0.6	1.2	0.9	1.7	1.1
Geranyl acetate	20,255	1384	0.6	0.6	0.2	0.2	0.9	0.6	1.1	1.1
β-Cubebene	20,419	1387	1.1	1.1	0.5	0.5	1.1	0.8	1.3	0.9
β-Elemene	20,518	1389	2.9	2.9	0.5	0.5	2.9	1.9	3.8	3.2
Dodecanal	21,254	1407	0.2	0.2	0.1	0.1	0.1	0.1	0.3	0.2
Limonen-10-yl acetate	21,349	1409	0.3	0.3	0.1	0.1	0.5	0.3	0.7	0.3
trans-Caryophyllene	21,572	1415	1.2	1.2	0.3	0.3	1.1	0.8	1.6	1.5
α-Guaiene	22,373	1436	0.2	-	0.1	-	0.2	0.1	0.3	0.1
α-Humulene	22,953	1450	2.1	2.0	0.5	0.5	2.4	1.4	2.8	2.6
Germacrene D	24,085	1477	5.0	4.9	1.9	1.9	5.5	3.2	7.2	7.6
Valencene	24,564	1489	0.3	0.3	0.1	0.1	0.6	0.3	0.4	0.9
Bicyclogermacrene	24,698	1492	1.1	1.1	0.3	0.3	1.6	0.9	1.9	2.8
α-Muurolene	24,873	1496	-	-	0.1	0.2	-	-	0.7	0.9
Eremophilene	25,064	1500	10.4	10.4	2.6	2.8	11.1	7.2	15.2	18.6
(E,E)-α-Farnesene	25,294	1506	7.6	7.5	3.5	3.5	8.8	5.3	12.8	15.8
δ-Cadinene	25,808	1520	1.9	1.9	0.7	0.7	1.7	1.1	2.6	3.2
Elemol	26,833	1547	0.2	0.2	-	-	0.1	0.1	0.2	0.1
Germacrene B	27,026	1552	0.9	0.9	0.3	0.3	0.9	0.5	1.4	1.7
Dodecanoic acid	27,640	1568	0.2	0.2	-	-	0.1	-	0.3	0.9
Spathulenol	27,873	1574	0.1	-	-	-	-	-	-	-
Tetradecanoic acid	34,903	1764	0.6	0.7	0.2	0.3	0.4	0.3	0.8	2.6
Hexadecanoic acid	41,697	1966	1.8	2.4	0.6	1.1	2.0	1.4	5.4	4.8
Linoleic acid	47,065	2132	0.5	0.5	0.6	1.0	2.1	0.9	4.2	11.3

RESULTS

pharmaceuticals

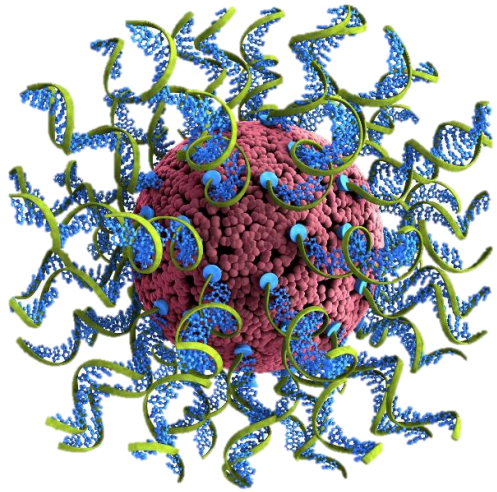
Article

Preparation of Multifunctional N-Doped Carbon Quantum Dots from *Citrus clementina* Peel: Investigating Targeted Pharmacological Activities and the Potential Application for Fe^{3+} Sensing

Silvija Šafranko [1], Anamarija Stanković [2], Sugato Hajra [3], Hoe-Joon Kim [3], Ivica Strelec [1], Maja Dutour-Sikirić [4], Igor Weber [5], Maja Herak Bosnar [6], Petra Grbčić [7], Sandra Kraljević Pavelić [8], Aleksandar Széchenyi [9], Yogendra Kumar Mishra [10], Igor Jerković [11,*] and Stela Jokić [1,*]

CITRUS PEEL AS A CARBON SOURCE IN CARBON QUANTUM DOTS TECHNOLOGY

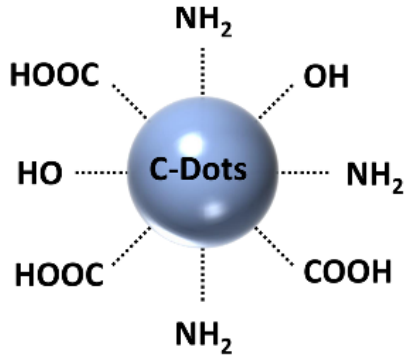
Investigating the potential biological activity and applications in biomedicine



Citrus clementina waste

Biomass waste
+ Amino acid

180 °C, 12 h



POTENTIAL APPLICATIONS

1. Antioxidant activity
2. Antitumor effect
3. Fe^{3+} sensing
4. Cellular imaging
5. Fluorescent ink

BIOMASS CAN BE USED AS A CARBON SOURCE FOR CQDs PREPARATION

RESULTS

Contents lists available at ScienceDirect

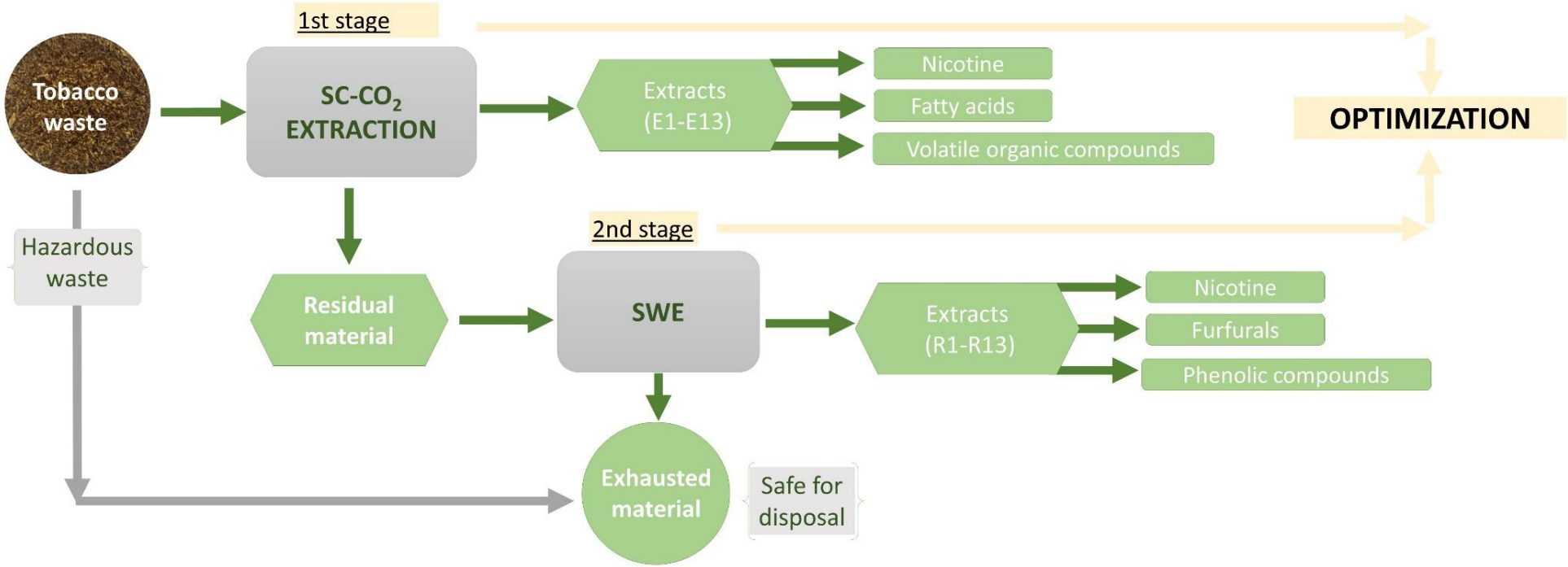
Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Sequence of supercritical CO_2 extraction and subcritical H_2O extraction for the separation of tobacco waste into lipophilic and hydrophilic fractions

Marija Banožić[a,], Tanja Gagić[b], Maja Čolnik[b], Željko Knez[b], Mojca Škerget[b], Igor Jerković[c], Stela Jokić[a]*

Tobbaco waste (dust, midrib, scrap)



Contents lists available at ScienceDirect

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Sequence of supercritical CO_2 extraction and subcritical H_2O extraction for the separation of tobacco waste into lipophilic and hydrophilic fractions

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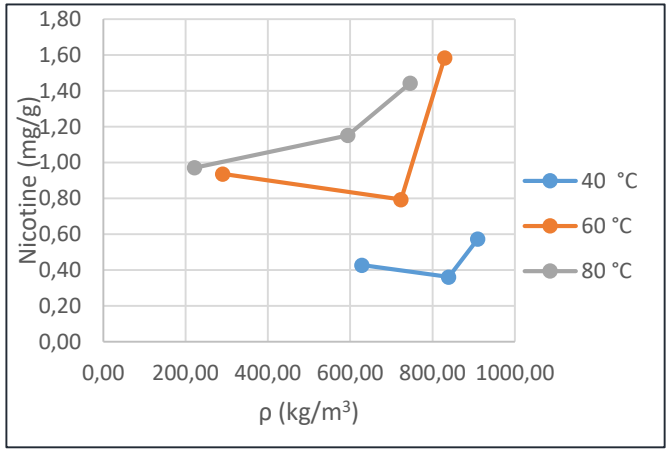
SUPERCRITICAL CO_2 EXTRACTION

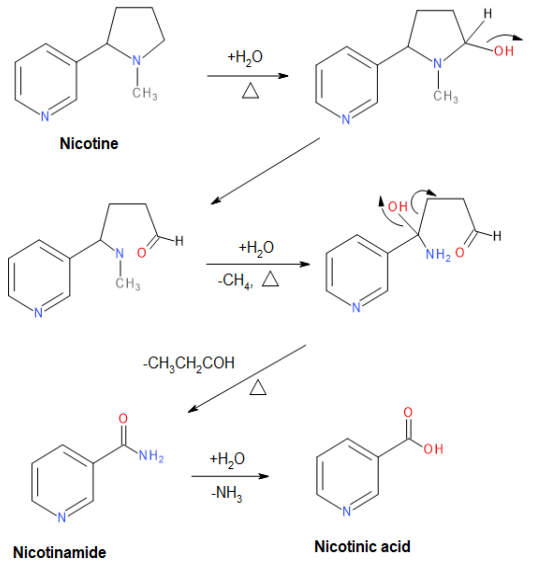
Tested variables	Pressure (bar)	Temperature (°C)	Time (min)
Experimental range	100-300	40-80	5-120
Detected compounds	Fatty acids, nicotine, volatile organic compounds		
Optimal conditions	Type: scrap, 120 min, 300 bar and 61.22 °C		

RUN	Pressure (bar)	Temperature (°C)	Nicotine (mg/g)	Other detected compounds
E1	100	40	4.28	*Duva-4.8.13-triene-1.3-diol*
E2	300	40	5.74	*2.3'-Dipyridyl*
E3	100	80	9.71	*3-Oxo-α-ionol*
E4	300	80	14.43	*Cotinine*
E5	100	60	9.37	*Solavetivone*
E6	300	60	15.85	*Neophytadiene*
E7	200	40	3.62	*Hexahydrofarnesyl acetone*
E8	200	80	11.52	*(E.E)-Farnesyl acetone*
E9	200	60	9.03	*Hexadecanoic acid*
E10	200	60	7.96	*Thunbergol*
E11	200	60	7.62	*Phytol*
E12	200	60	8.31	Fatty acids (palmitic acid, stearic acid, linoleic acid, linolenic acid, oleic acid
E13	200	60	6.76	
Soxhlet			8.34	



Nicotine content of tobacco waste *vs*. solvent density (ρ) at different temperatures during SC-CO_2 extraction

Proposed degradation mechanism:



SUBCRITICAL-WATER EXTRACTION

Tested variables	Time (min)	Temperature (°C)	Solvent/solid ratio (mL/g)
Experimental range	5-25	150-250	10-30
Detected compounds	Phenolic compounds, carbohydrates, chlorogenic acid, rutin, nicotine, 3.4 DHBA, nicotinic acid, nicotinamide, 5-HMF, furfural and 5-MF		
Optimal conditions	Scrap: 150 °C. 23 min. 28 mL/g	Dust: 160 °C. 20 min. 10 mL/g	Midrib: 150 °C. 25 min. 30 mL/g

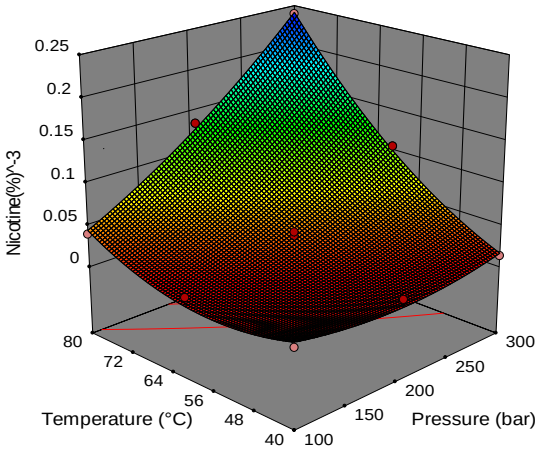
Nicotine mg/g			
	SCRAP	DUST	MIDRIB
1	26.6	15.0	9.07
2	44.3	22.8	19.7
3	46.1	23.1	12.3
4	29.9	18.0	10.2
5	33.5	27.2	13.0
6	51.4	27.5	17.7
7	32.5	21.5	11.0
8	42.4	32.2	17.1
9	40.5	24.3	14.8
10	42.5	29.5	15.7
11	30.6	21.7	12.5
12	39.4	23.6	14.7
13	32.01	26.9	13.0
14	37.1	28.0	15.2
15	32.4	26.4	13.3
16	32.4	24.5	14.1
17	32.1	27.8	14.0

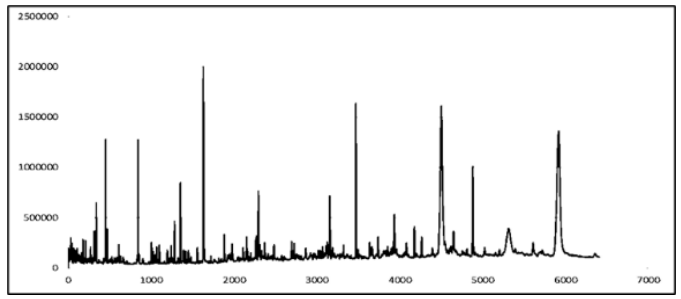
SEQUENCE OF SUPERCRITICAL CO_2 EXTRACTION AND SUBCRITICAL WATER EXTRACTION

Tested SFE variables	Pressure (bar)	Temperature (°C)	Time (min)
Experimental range	100-300	40-80	5-120
Tested SWE variables	Temperature (°C)	Time (min)	Solvent: solid ratio (mL/g)
Experimental conditions	150	23	28
Detected compounds	Nicotine, Phenolic compounds, nicotinic acid, nicotinamide,5-HMF, furfural and 5-MF		
Optimal conditions	Type: scrap, SFE 120 min. 300 bar and 61.22 °C		

RUN	Extraction yield (%)	Nicotine (mg/g)	Nicotinamide (mg/g)	Nicotine acid (mg/g)
R1	54.08	46.70	4.02	2.39
R2	59.15	42.10	3.71	1.87
R3	58.34	29.30	3.04	1.43
R4	74.05	16.10	1.98	1.18
R5	52.47	42.90	4.28	2.22
R6	65.83	21.10	2.58	1.33
R7	51.39	45.60	4.25	2.19
R8	54.50	19.50	3.03	1.47
R9	53.62	31.40	3.46	2.05
R10	56.50	36.40	3.65	1.72
R11	60.42	30.00	3.07	1.62
R12	52.68	30.20	3.29	1.59
R13	54.77	28.70	3.03	1.54
Raw material	54.57	38.10	3.15	22.58

Two-stage extraction process (SC-CO_2 extraction followed by SWE) can enhance the extraction efficiency due to the elimination of fats during SC-CO_2 extraction which enables better dissolution of the other compounds in subcritical H_2O.

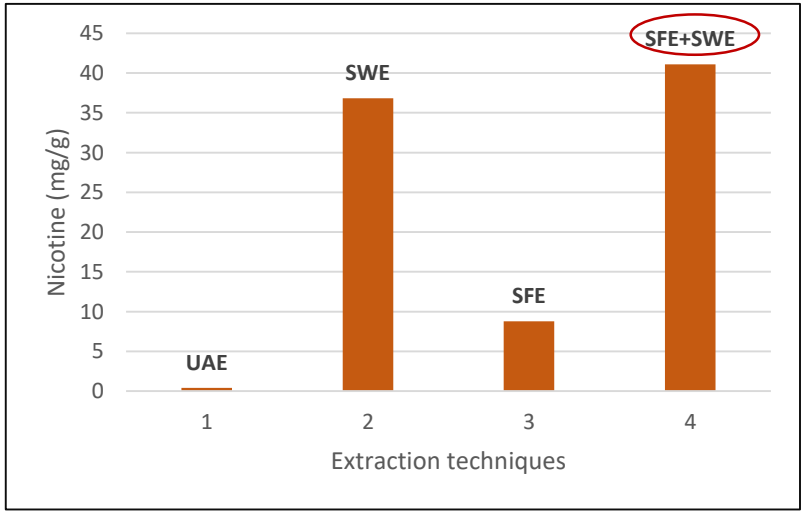




GC-MS midrib chromatogram obtained after SFE

Proposed model:

$$Y_1^{-3} = 0.0369 + 0.0495X_1 + 0.0634X_2 + 0.0491X_1X_2 + 0.0148X_1^2 + 0.0279X_2^2$$



Comparison of different methods in extraction of nicotine form tobacco waste

RESULTS

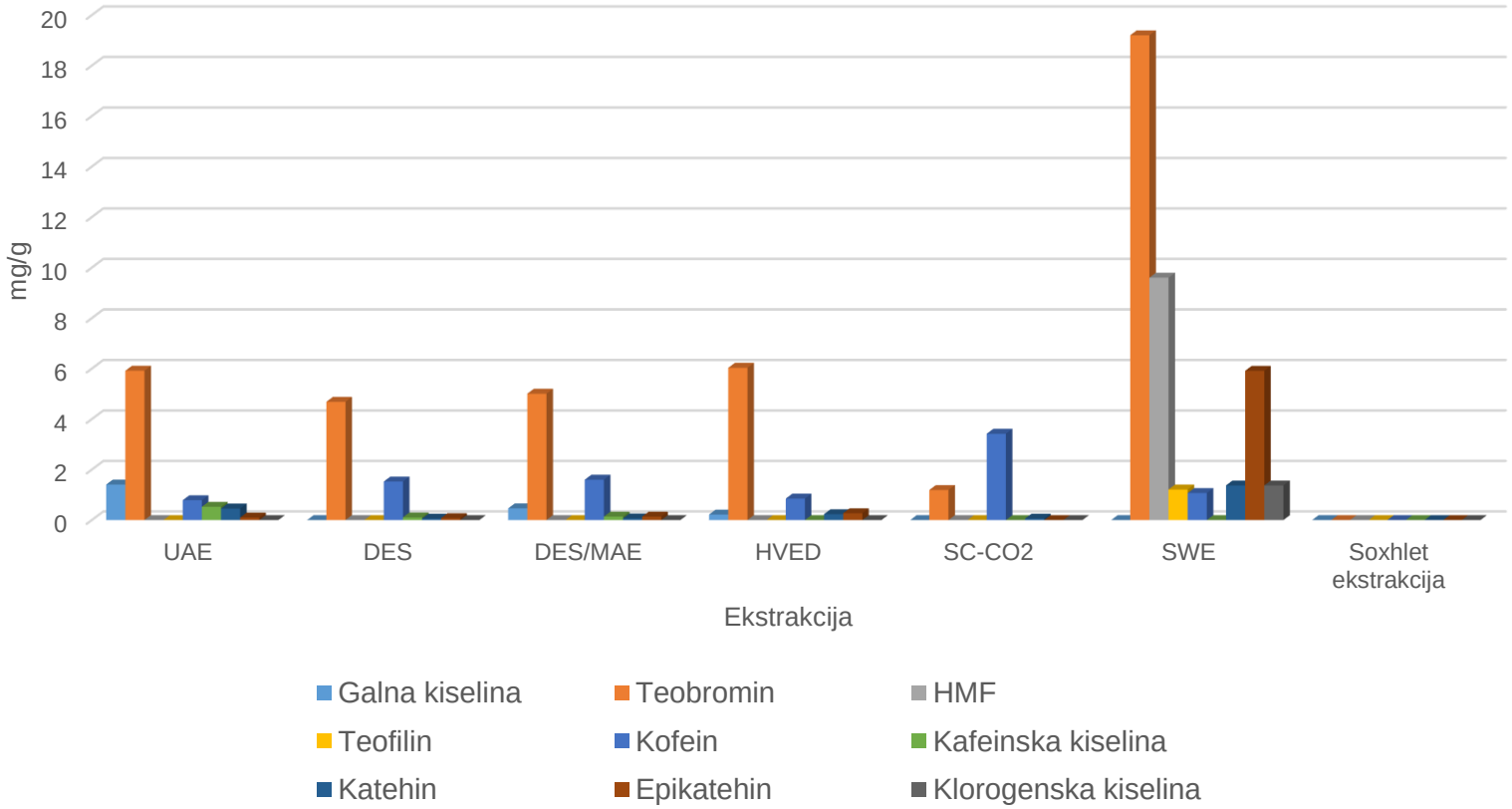
molecules

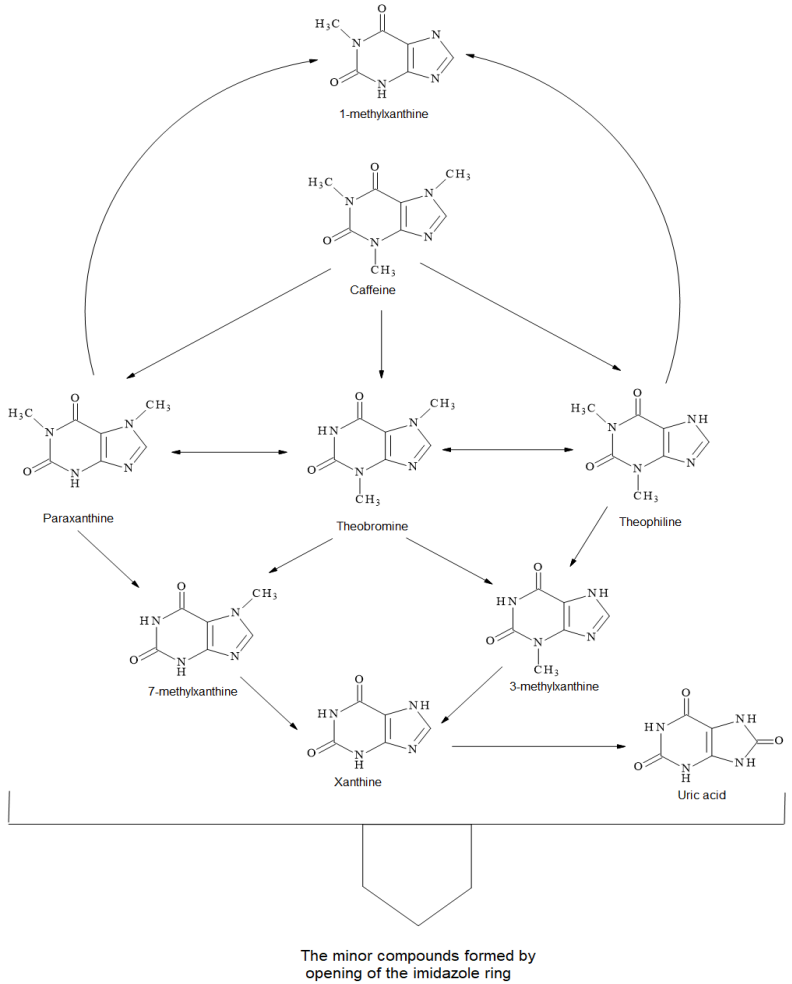
MDPI

Article

Separation of Active Compounds from Food by-Product (Cocoa Shell) Using Subcritical Water Extraction

Stela Jokić [1,*], Tanja Gagić [2], Željko Knez [2,3], Drago Šubarić [1] and Mojca Škerget [2]





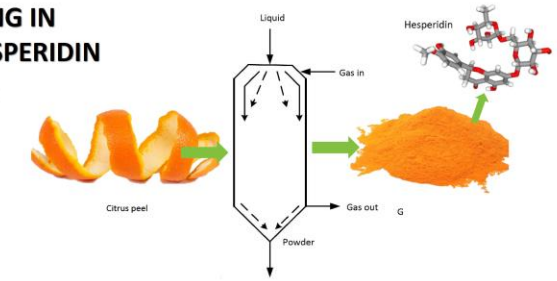
Scheme 1. Proposed degradation mechanism of methylxanthines within hydrothermal degradation of cocoa shell.

3rd International conference Food industry by-products
29th August 2022, Osijek, Croatia

APPLICATIONS OF SPRAY-DRYING IN MICROENCAPSULATION OF HESPERIDIN DELIVERED FROM CITRUS PEEL

Marija Banožić[1*], Krunoslav Aladić[1], Małgorzata Krzywonos[2], Hanna Pińkowska[3], Igor Mucha[4], Adrianna Złocińska[4], Stela Jokić[1]

[1]Faculty of Food Technology, Josip Juraj Strossmayer University of Osijek, Franje Kuhača 18, 31000 Osijek, Croatia
[2] Business and Management Faculty, Wroclaw University of Economics and Business, Komandorsko 118/120, 53-345 Wrocław, Poland
[3] Faculty of Production Engineering, Wroclaw University of Economics and Business, Komandorsko 118/120, 53-345 Wrocław, Poland
[4]Faculty of Pharmacy, Wroclaw Medical University, Borowska 211A, 50-556 Wrocław, Poland
*mbanozic@ptfos.hr



INTRODUCTION

Citrus fruits are one of the most important crops with worldwide production, while citrus by-products represent a problem regarding their disposal due to the environmental risk. The citrus peel contains hesperidin, a flavonoid with a wide range of biological activities. Recent scientific literature discusses the extraordinary versatility of hesperidin, which is reflected in its antioxidant, anti-inflammatory, cardio-protective and antidiabetic properties. However, hesperidin is quite unstable and therefore should be encapsulated to protect its bioactivity from the effects of environmental conditions. Among the other popular microencapsulation techniques, spray drying allows rapid evaporation of water and maintains a relatively low temperature within the particles. The aim of this study was to investigate the possibility of applying spray drying technique for the encapsulation of hesperidin from mandarin peel (*Kuno* variety), formed as by-products during the growth and fresh fruit processing.

METHODS

Samples (whole citrus fruits, satsuma mandarin, Citrus unishu, medium late variety Kuno) were obtained from family farm OPG Pačić. Citrus fruits were grown and harvested in the Metković, Neretva Valley, Croatia in the season 2021/2022. After harvesting, the peel was removed and stored at -80 °C. Before extraction peel was dried, grounded at a laboratory mill and sieved. Citrus peel extracts were produced by ultrasonic-assisted extraction with 70% ethanol as a solvent. Carriers (maltodextrin and Arabic gum) were added to feed in the amount of 100% compared to the dry matter of the extract. The feed flow rate was adjusted to 4 ml/min, the airflow rate was 283 L/h and the temperature of drying was 120 °C. Microcapsules were separated using a high-performance cyclone and collected in the collecting chamber, weighted and stored until further analysis. Determination of hesperidin was performed using high-performance liquid chromatography, and microcapsules were characterized using Powder X-Ray diffraction analysis, Fourier-transform infrared spectroscopy and thermogravimetric analysis.
Encapsulation efficiency was calculated using equation:

$$EE=(THC-SHC)/THC$$

where THC is total hesperidin content and SHC is surface hesperidin content.

RESULTS

Table 1 Encapsulation efficiency of hesperidin microcapsules produced using spray drying

No	Samples	Total hesperidin content [μg ml^{-1}]	Surface hesperidin content [μg ml^{-1}]	Encapsulation efficiency (EE) [%]
1	CPE+MD+SD	461.025	261.332	43.32
2	CPE+GA+SD	433.760	400.940	7.56

CPE – citrus peel extract
MD - maltodextrin, GA - gum Arabic, SD - spray drying

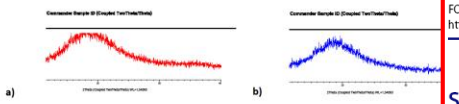


Figure 1 . PXRD patterns for Hesperidin microparticles a)maltodextrin b)Arabic gum

Figure 1 presents PXRD diffractograms of hesperidin microparticles. Few patterns were observed in hesperidin microparticles which showed few peaks with different peak intensities. These findings provide evidence that hesperidin microparticles were lost its crystalline structure during encapsulation processes.

The FTIR spectra of hesperidin as pure compound, hesperidin microparticles were recorded in the range from 400 to 4000 cm^{-1} and compared in **Figure 2.** In hesperidin microcapsules, the peaks existent in frequencies between 2900 cm^{-1} to 3500 cm^{-1} were predominantly found pertaining to hydrogen bonds (O-H stretch), carboxylic acids and residual water. The band around 1604 was assigned to the carbonyl (C=O) stretching in microcapsules with maltodextrin.

TGA data suggest that the thermal degradation of the hesperidin microparticles is a complex process, which occurs in several stages as evidenced by the presence of several peaks in the TGA curve in **Figures 3.** This is likely a consequence of citrus peel complex chemical composition, which is characterized by the presence of several macrocomponents (i.e., pectin, cellulose, hemicelluloses, and lignin) and minor constituents (e.g., proteins, fats, phenolic compounds, etc.) in varying proportions. Hesperidin microcapsules with maltodextrin were thermally stable up to the temperature of about 125 °C while and decomposed in three-stage, while microcapsules with gum Arabic were thermally stable up to the temperature of approximately 115 °C and decomposing in two stages.

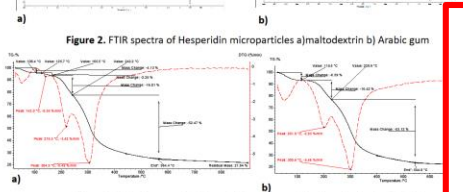


Figure 2. FTIR spectra of Hesperidin microparticles a)maltodextrin b) Arabic gum

Figure 3. TGA diagrams for Hesperidin microparticles a)maltodextrin b) Arabic gu

CONCLUSION

While dealing with pure flavonoid-hesperidin is more convenient from an analytical standpoint, non-purified phenolic extracts are more commercially viable, saving time, cutting costs, and delivering the largest yield of polyphenols without waste. Citrus peel showed as a possible alternative to commercial hesperidin sources, while spray drying showed as a reliable and effective tool for its encapsulation. The amorphous form of bioactive compounds, such as hesperidin represents the most energetic solid state, which provides the greatest advantage in terms of solubility and bioavailability. The hesperidin retention in the microcapsules was 461.03 and 433.76 mg/g for microcapsules encapsulated with maltodextrin and gum Arabic, respectively. However, higher encapsulation efficiency (difference between surface and total hesperidin content) and highest thermal stability was achieved when maltodextrin was used as an encapsulating agent.

HRZZ
Acknowledgments:
This work has been supported by Croatian Science Foundation under the project "Application of innovative techniques of the extraction of bioactive components from by-products of plant origin" (UIP-2017-05-9909)
ByProExtract

FOOD REVIEWS INTERNATIONAL
https://doi.org/10.1080/87559129.2021.1938601
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Spray Drying as a Method of Choice for Obtaining High Quality Products from Food Wastes– A Review

Marija Banožić[a], Jelena Vladić[b], Ines Banjari[a], Darko Velić[a], Krunoslav Aladić[a], and Stela Jokić[a]

sustainability
MDPI
Article

An Approach to Value Cocoa Bean By-Product Based on Subcritical Water Extraction and Spray Drying Using Different Carriers

Stela Jokić [1,*], Nataša Nastić [2], Senka Vidović [2], Ivana Flanjak [1], Krunoslav Aladić [1] and Jelena Vladić [2,*]

12 hranom do zdravlja with food to health

RECYCLING OF FOOD INDUSTRY BY-PRODUCTS: PRODUCTION OF COCOA BEAN SHELL POWDER USING SPRAY DRYING TECHNIQUE

Jelena Vladić[1], Senka Vidović[1], Ivana Flanjak[2], Mojca Škerget[3], Stela Jokić[2*]

[1]University of Novi Sad, Faculty of Technology, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia
[2]Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 20, 31000 Osijek, Croatia
[3]University of Maribor, Faculty of Chemistry and Chemical Engineering, Smetanova 17, 2000 Maribor, Slovenia
*stela.jokic@ptfos.hr

Introduction

Cocoa bean shell, which represents waste generated in the production of cocoa and its products, is proven to contain numerous bioactive components that can be applied in food, cosmetic, and pharmaceutical industry. To valorize this material, it is necessary to develop an adequate method that can provide quality and stabile products of cocoa bean shell that contains bioactive components. With that goal in mind, the spray drying technique with two carriers – maltodextrin and whey protein was applied.

Methods

The obtained dry extracts were characterized in terms of physico-chemical properties: moisture content, hygroscopicity, bulk density, rehydratation, water absorption index and water solubility index, content of total phenols and total flavonoids. Furthermore, the content of bioactive components (theobromine, caffeine, gallic acid, caffeic acid, p-coumaric acid, (+)-catechin, (-)-epicatechin and (-)-epicatechin gallate) was performed by HPLC method.

Results and discussion

By using maltodextrin, an approximately 74% efficacy of the process was achieved, while with whey protein it was 59%. The powders obtained with both carriers had a moisture content below 6%, which secures the extended stability of the extract if it is stored in an adequate manner. Similar results were achieved in the case of hygroscopicity which is the capacity of the material to absorb moisture. This capacity was monitored after 2, 5, 7, 10, and 14 days and it ranged from 12.40 to 16.68% for both powders.

The value of the bulk density of the obtained powders were higher in the case where maltodextrin was used, while whey protein was more efficient and adequate carrier for the preservation of polyphenols. As a result, a higher content of total phenols and flavonoids in dry powders dried with whey protein was determined. Higher content of methylxanthines and phenolic acids, except caffeic acid, was obtained when whey protein was used as a carrier while the content of other analyzed active components was the same regardless of carrier type.

Table 1. Powder characterization

Carrier	Efficiency (%)	Moisture content (%)	Rehidratation (s)	Bulk density (mg/mL)	WSI (%)	WAI (%)
Maltodextrin	73.52	5.54	5.3	421.58	62.4	29.6
Whey protein	58.61	5.83	4.3	302.43	72.8	12.8

e 1. HPLC analyses of phenols

Carrier	Maltodextrin	Whey protein
Gallic acid	0.37	0.48
Catechin	1.48	1.47
catechin	0.15	0.11
feic acid	0.04	0.03
echin gallate	0.07	0.06
maric acid	0.02	0.03

Table 2. HPLC analyses of methylxanthines

Carrier	Maltodextrin	Whey protein
Teobromine	5.95	7.34
Caffeine	1.10	1.34

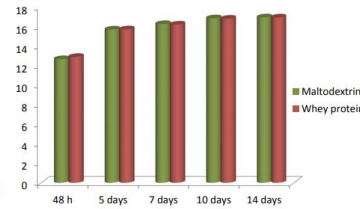
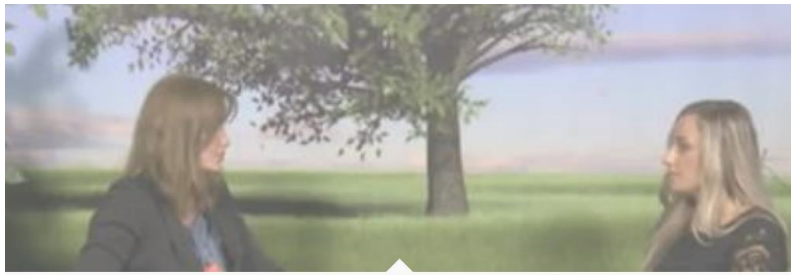


Figure 1. Hygroscopicity (%)

PROJECT PROMOTION



Osijek Television show „In Step with Nature“

On July 1st, 2018, in the emission "In Step with Nature" show...

01/07/2018

Osječka TV

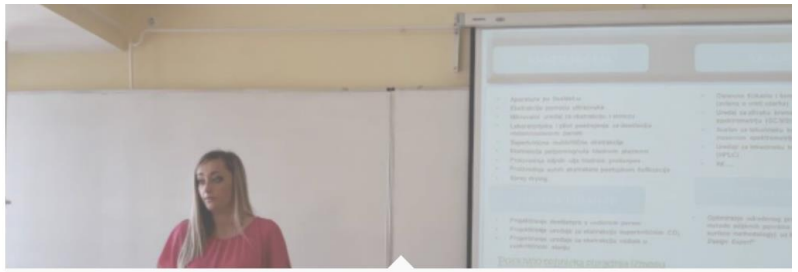
In the emission „Produženi vikend“ on Osječka TV on June...

18/06/2018

Media presentation of the project on HRT 2

In the emission "Index" (science and education program) on HRT...

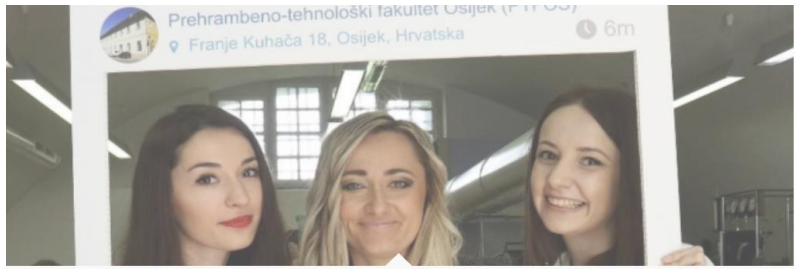
28/03/2018



Popular Lecture at Faculty of Technology Novi Sad

Principal Investigator Stela Jokić, PhD, give a popular lecture...

04/06/2018



Science Festival at the Faculty of Food Technology

Faculty of Food Technology Osijek traditionally continues to...

17/04/2018

Media promotion of the project – agrobiz.hr

Croatian agricultural web portal Agrobiz.hr published an article...

12/02/2020

PROJECT PROMOTION


MALA SREDINA ODAVNO NIJE PREPREKA ZA USPJEH

Iz općine Čačinci uskoro čak pet doktora znanosti

Dvoje znanstvenika titulu već ima, troje ih je na najboljem putu da je stekne

Short interview about the project and research of PhD student Silvija Šafranko

The short article about the five PhD students from the small...

28/10/2021


DOKTORANDICE S PREHRAMBENO-TEHNOLOŠKOG FAKULTETA OSIJEK U POSJETU SVEUČILIŠTU U CZESTOCHOWI (POLJSKA)

Stela JOKIĆ

razdoblju od 30. kolovoza 21. do 19. rujna 2021. zaposle- ce Prehrambeno-tehnološkog

University Gazette (No. 73) about the research visit to Czestochowa (Poland)

Please click on the image to enlarge.

22/10/2021


znanstveno-stručni skup „FOOD INDUSTRY BY-PRODUCTS"

2. FIB Conference and Project promoted in the University Gazette (No. 71)

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23/07/2021


FAKULTET OSIJEK

„PRIMJENA INOVATIVNIH TEHNIKA EKSTRAKCIJE BIOAKTIVNIH KOMPONENTI IZ NUSPROIZVODA BILJNOGA PODRIJETLA BYPROEXTRACT"

Osijek
- Voditelj projekta: prof. dr. sc. Stela Jokić
- Vrijednost projekta: 1.607.708,72 kuna
- Razdoblje trajanja provedbe projekta: 1. 1. 2018. – 1. 1. 2023.
- Izvor financiranja: Hrvatska zaklada za znanost; Uspostavni istraživački projekt UIP-2017-05-9909
- Uspostavni istraživački projekt HRZZ-a

Project promoted in the University Gazette (No. 69)

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21/05/2021


S FAKULTETA I ODJELA

REHRAMBENO-TEHNOLOŠKI FAKULTET OSIJEK Započela realizacija nekoliko važnih znanstvenih i stručnih projekata

Odobreno financiranje projekata vrijednih gotovo 4,8 milijuna kuna

Project promoted in the University Gazette (No. 33)

Please click on the image to enlarge.

11/02/2018


230

Od industrijskog otpada do vrijednih bioaktivnih komponenti

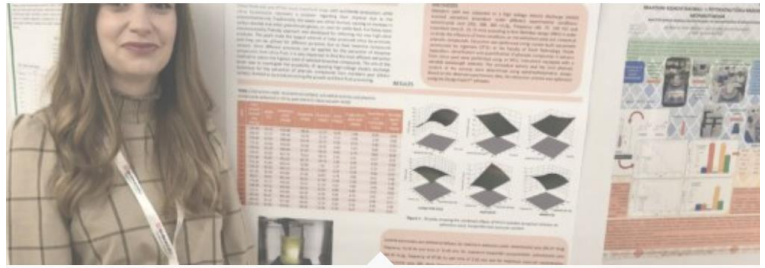
Skup mladih zn 2. Dani mla 23. – 24. svibnja 20

Project promoted twice in the scientific journal "Chemistry in Industry"

The ByProExtract project under the coordination of Stela Jokić,...

30/07/2019

CONFERENCES



XIV Meeting of Young Chemical Engineers 2022

Silvija Šafranko and Marija Banožić, ByProExtract team members...

25/02/2022

4th Conference: “Tobacco and tobacco products: yesterday, today, tomorrow”

Stela Jokić, project leader and Marija Banožić, ByProExtract...

11/02/2022

2nd International Student GREEN Conference in Osijek

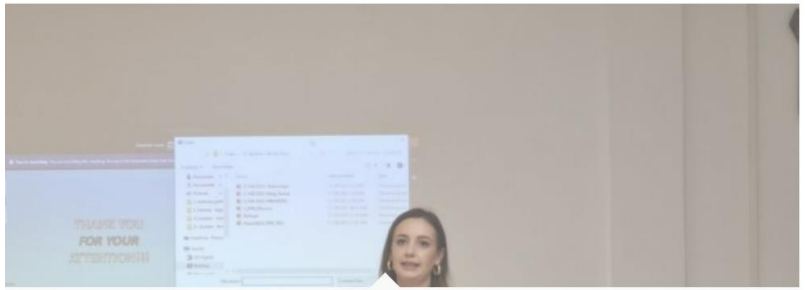
ByProExtract team members with their students participated in...

03/06/2022

5th Mini Symposium of Section of Medicinal and Pharmaceutical Chemistry

ByProExtract team member, Silvija Šafranko, participated on...

30/11/2021



Third Young Scientists Days in Osijek

ByProExtracts team members participated on the 3rd „Young Scientist...

30/11/2021

World Congress on Food Safety and Nutrition Science – Rome, Italy

A conference “World Congress on Food Safety and Nutrition Science”...

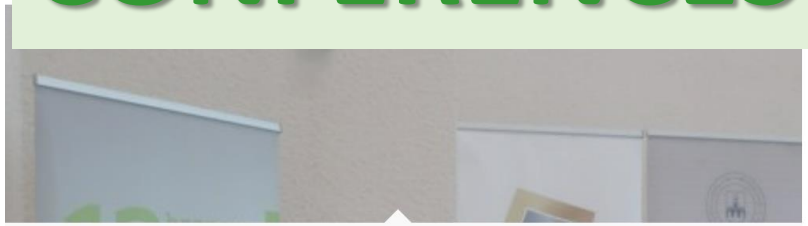
26/10/2021

CONFERENCES

2. International Scientific-Professional Conference FOOD INDUSTRY BY-PRODUCTS

Second International Scientific Conference FOOD INDUSTRY BY-PRODUCTS...

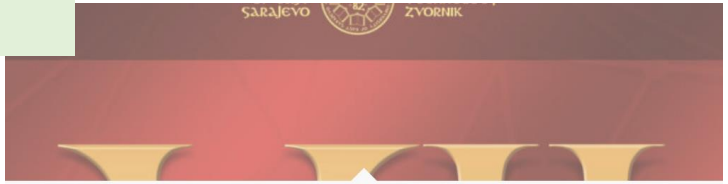
28/06/2021



13th International Scientific and Professional Conference „WITH FOOD TO HEALTH“

The 13th International Scientific and Professional Conference...

17/09/2021



7th International Congress “Engineering, Environment and Materials in Process Industry

The international congress on Engineering, Environment and Materials...

19/04/2021

CHISA 2021 Virtually

ByProExtracts team members participated on CHISA 2021 Virtually,...

18/03/2021

Conference: “Tobacco and tobacco products: yesterday, today, tomorrow”

Stela Jokić, project leader and Marija Banožić, ByProExtract...

17/12/2020

International Conference 18th Ružička Days “Today Science – Tomorrow Industry”

International Conference 18th Ružička Days was traditionally...

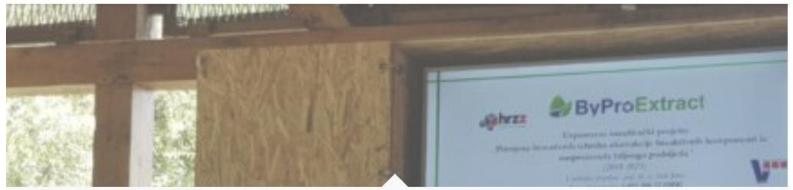
18/09/2020

CONFERENCES

XIII Meeting of Young Chemical Engineers 2020

Silvija Šafranko and Marija Banožić, ByProExtract team members...

21/02/2020



International scientific-professional conference FOOD INDUSTRY BY-PRODUCTS (HRZZ)

The International Scientific Conference FOOD

12th International Scientific and Professional Conference „WITH FOOD TO HEALTH“

The 12th International Scientific and Professional Conference...

25/10/2019

ICAPP Conference – Novi Sad (Serbia)

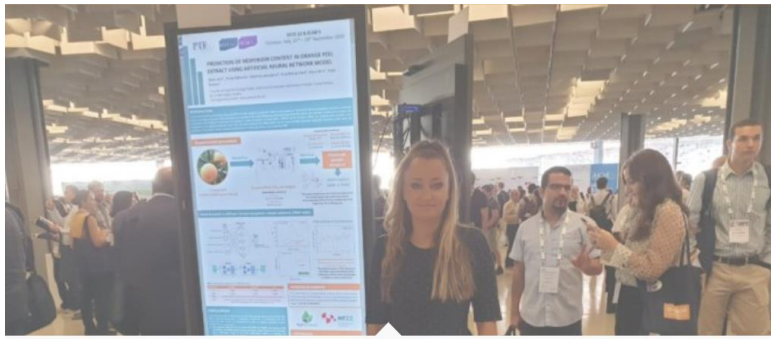
First Conference on Advanced Production and Processing – ICAPP...

11/10/2019

Slovenian Chemical Society Annual Meeting 2019

Marija Banožić, ByProExtract team member participated at Slovenian...

27/09/2019



ECCE12 & ECAB5 Congress in Italy

ByProExtracts team members participated on ECCE12 & ECAB5,...

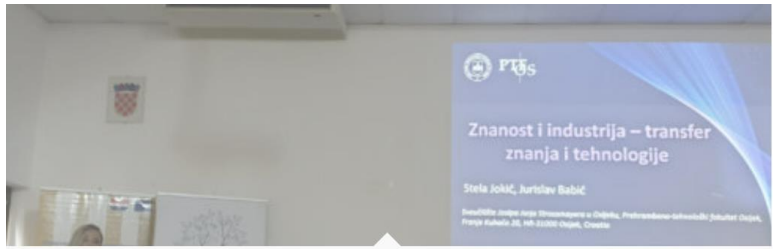
19/09/2019

CONFERENCES

Flour-Bread ’19 Congress

The 10th International Congress “Flour-Bread ’19” and the...

14/06/2019



Second Regional meeting held in Vinkovci

Second Regional meeting “2. Regionalni skup o mogućnostima...

07/06/2019

Second Young Scientists Days in Osijek

ByProExtracts team members participated on 2nd „Young Scientist...

24/05/2019

Marija Banožić held oral presentation on 2. ZORH Meeting

The second Meeting of scientists, experts and students in the...

27/04/2019

26th Croatian Meeting of Chemists and Chemical Engineers

ByProExtracts team members participated on 26th meeting of Croatian...

10/04/2019

2nd International Congress on Food Safety and Quality held in Opatija

Our project team member, Ines Banjari participated as an invited...

16/11/2018

CONFERENCES

Marija Banožić participated at 6th Conference of Young Chemists

Marija Banožić, ByProExtract team member participated at 6th...

27/10/2018

11th International Scientific and Professional Conference WITH FOOD TO HEALTH

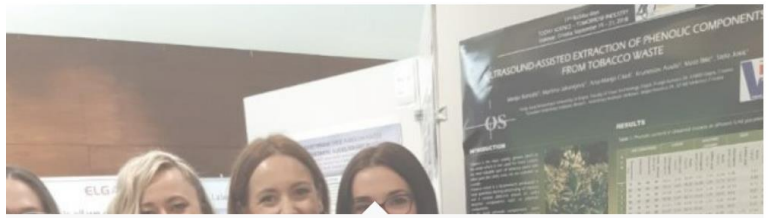
The 11th International Scientific and Professional Conference...

18/10/2018

9th International Congress of Food Technologists, Biotechnologists and Nutritionists

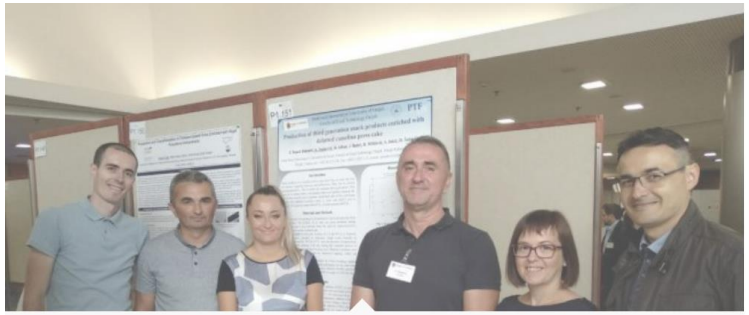
The 9th International Congress of Food Technologists, Biotechnologists...

03/10/2018



International Conference 17th Ružička Days "Today Science – Tomorrow Industry"

International Conference 17th Ružička Days was traditionally...



CHISA 2018 – Prague

Principal Investigator Stela Jokić, PhD had participated on...

26/08/2018

Principal Investigator Stela Jokić held a popular lecture in Kopački rit

Within the workshop entitled „Food industry by-products:...

04/05/2018

EXCHANGE

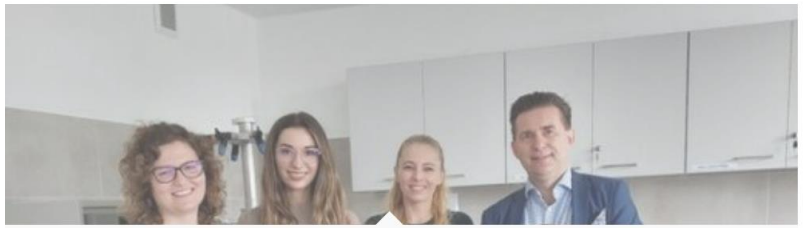
Silvija Šafranko visited University of Pecs (Hungary) within the ERASMUS Programme

Silvija Šafranko, ByProExtract team member, stayed on the Institute...

Research visit of Marija Banožić from the Faculty of Food Technology Osijek to Wroclaw (Poland)

In the period between March 11th and April 8th, Marija Banožić...

08/04/2022



Research visit of PhD Students from Faculty of Food Technology Osijek to Czestochowa (Poland)

In the period between August 30th and September 19th two PhD...

Team Members at the Erasmus Exchange on Faculty of Technology, Novi Sad (Serbia)

Krunoslav Aladić and Marija Banožić, ByProExtract project...

28/07/2021

Jelena Vladić, PhD completed a research stay at BOKU University in Vienna

Jelena Vladić, PhD completed a research stay at the BOKU University...

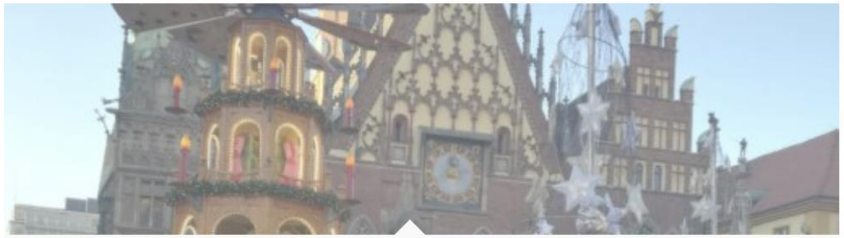
08/09/2020

Team members visited Faculty of Technology, Novi Sad (Serbia)

ByProExtract project team members from Faculty of Food Technology...

10/02/2020

EXCHANGE



Marija Banožić at the student exchange on Wroclaw Medical University, Poland

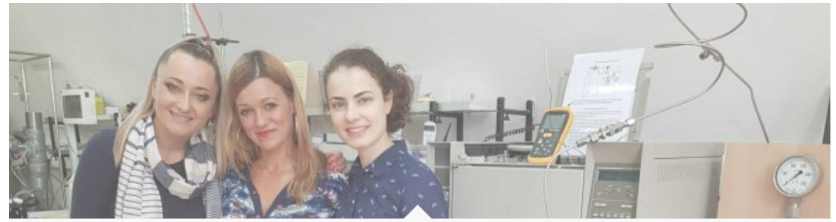
Marija Banožić, ByProExtract team member, has attended on student...

04/12/2019

Marija Banožić at the student exchange on Faculty of Chemistry and Chemical Technology in Maribor

Marija Banožić, ByProExtract team member, has attended on student...

24/03/2019



Project team members from Faculty of Technology Novi Sad in Osijek

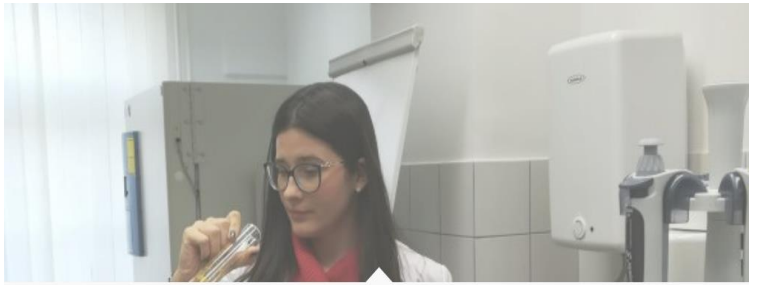
As part of the Erasmus program at the Faculty of Food Technology...

17/07/2018

Prestigious US Department of State fellowship for our team member

Our team member, Ines Banjari, PhD, Associate Prof. was nominated...

16/03/2019



PhD student from University of Caliagri on our Faculty

Kasia Gil, PhD student on University of Caliagri has attended...

03/12/2018

Advanced Statistics Training in London

From June 11 to June 14, 2019, at University College London,...

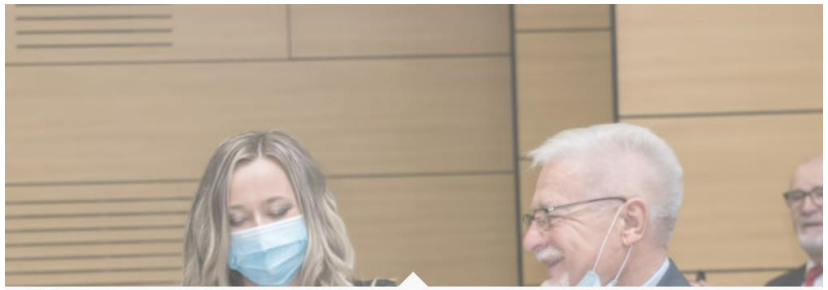
16/06/2019

AWARDS

Jelena Vladić, PhD winner of the Award “For Women in Science” for 2020

Jelena Vladić, PhD is one of the winners of the recognition...

05/01/2021



Stela Jokić, full professor received prestigious Award of HATZ

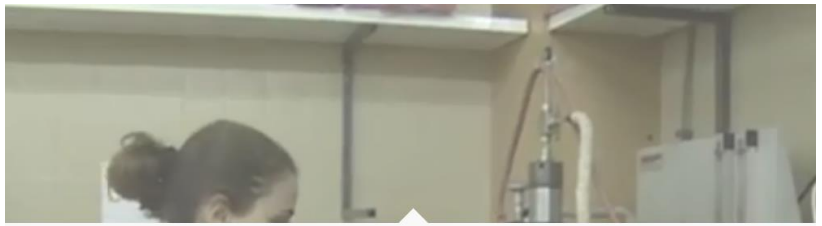
Stela Jokić, full professor and principal investigator of ByProExtract project...

24/10/2020

ByProExtract Team Leader Awarded with National Science Award

National Science Awards honoring the greatest achievements in...

16/12/2019



ByProExtract project team members – The best team of young scientists of Serbia

A project team member and research assistant of Faculty of Technology...

30/11/2018

SCIENCE POPULARIZATION

BioLab Team

PTF

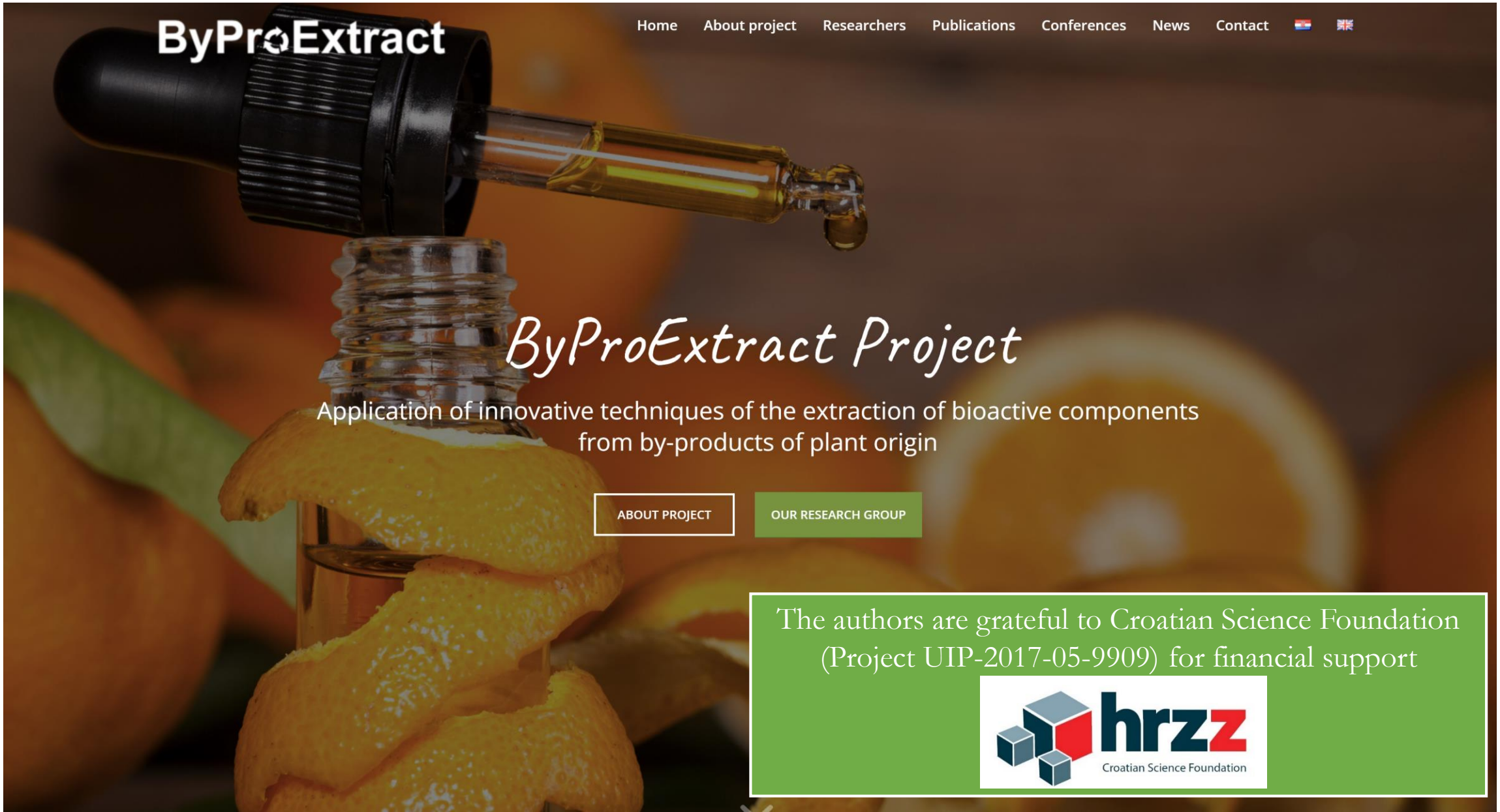
Follow us on Instagram

SCIENCE POPULARIZATION

European Researchers' Night


„Alone we can do so little;
Together, we can do so much."
- Helen Keller

Thank you for your attention!



The authors are grateful to Croatian Science Foundation (Project UIP-2017-05-9909) for financial support

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Croatian Science Foundation