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MARINE-DERIVED FUNGI PRODUCING RED ANTHRAQUINONES: NEW RESOURCES FOR NATURAL COLORS?



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² Ecole Supérieure d'Ingénieurs Réunion Océan Indien- ESIROI, Université de la Réunion, Sainte-Clotilde, Ile de la Réunion, France

Mireille FOULLAUD: mireille.fouillaud@univ-reunion.fr

Natural Colors make them better :

Red colors production through biotechnology :

Easily renewable resources for the production of natural red colorants are today under focus [1]. Marine-derived fungi are at the forefront in the search of new compounds of interest that could be produced through biotechnology [2]. In the field of colors, the marine-derived microfungi are able to synthesize a wide diversity of pigments/ hues, amongst which red anthraquinones are well represented [3]. Some of their main advantages are they are considered as natural, and their productions are « upscalable » in an industrial point of view.



The aim of our research is to develop a sustainable way to produce new natural colorants through microbial biotechnology

Red colors today:

In industries, authorized red pigments are mainly extracted from plants (as lycopene from tomato or betalains from beetroot), cochineal insects (carmine red) or from chemical synthesis. Their uses are more and more questioned with regard to the culture constraints or health problems. This work highlights the anthraquinoid red pigments known, up to date, from marine-derived fungi isolated from various biotopes all around the world. Thirty nine (39) compounds produced from about 25 strains have been already discovered. Beside the widespread *Aspergillus*, *Alternaria*, *Eurotium*, *Fusarium* or *Penicillium*, some original genera as *Halorosellinia*, *Nigrospora*, *Stemphylium* or *Curvularia* were identified as red anthraquinoid molecules's producers [4]. Some anthraquinones demonstrated interesting bioactive effects.

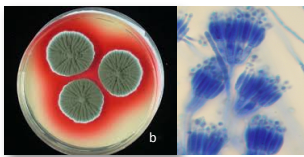


Fig. 1: *Penicillium* sp. strain (a) on solid medium / (b) Microscopic observation with lactophenol blue stain

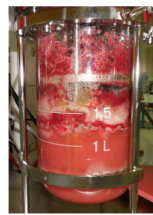
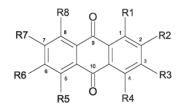


Fig. 2 : 1.5 L fermentor allowing fungal growth and pigments production



Fig. 3 : Red powder after liquid/liquid extraction



SZ-685C
 $C_{16}H_{18}O_8$ MW: 338

Marine derived sp.: *Halorosellinia* sp. No. 1403
 Origin : sediments collected in Jilantai salt field, Alashan, Inner Mongolia, China

Anticancer activity
 inducing apoptosis in tumor cell lines (human glioma, hepatoma, prostate cancer, MCF-7, MDA-MB-435 breast cancer...)

Carviolin
 $C_{16}H_{12}O_6$ MW: 300

Marine derived sp.: *Penicillium dravuni*
 Origin : endophyte from algae, Fidji

Moderate immunosuppressive activity
 against concanavalin A-induced (T cell) and LPS (lipopolysaccharides)-induced (B cell) proliferation of mouse splenic lymphocytes

4-deoxybostrycin
 $C_{16}H_{16}O_7$ MW: 320

Marine derived sp.: *Nigrospora* sp. 1403
 Origin : endophyte from mangrove plant, South China Sea

Inhibitory effects
 against clinical multidrug-resistant *Mycobacterium tuberculosis* strains

Lunatin
 $C_{15}H_{10}O_6$ MW: 286

Marine derived sp.: *Curvularia lunata*
 Origin : sponge-associated fungi from *Niphates olemda*, Indonesia

Antibacterial activity
 against *Staphylococcus aureus*, *Escherichia coli* and *Bacillus subtilis*

Erythroglaucin
 $C_{16}H_{10}O_4$ MW: 300

Marine derived sp.: *Aspergillus varicolor* B17
 Origin : sediments collected in Jilantai salt field, Alashan, Inner Mongolia, China

No bioactivity mentioned

Red Anthraquinones With or Without bioactivity?

- Many fungal red anthraquinoid compounds are known for their **bioactive effects**
 - Anticancer of **Alterporriols (K, L, M, W)** or **SZ685 C**, antibacterial of **Catenarin** or **Lunatin**, antiviral of **Alterporriols**
 - But others **did not demonstrate any clear toxic or bioactive effects**, up to now:
 - 6-methyl quinizarin**, **Austrocortinin**, **Altersolanol C**, **Erythroglaucin**, **Fusaquinon C**, **Rubrocristin**, **Tritisporin**...
- This could open the way to the introduction of new red compounds in daily products, **with or without** biological activities according to the use.
The aim of the future research will be to prove the bio-safety of the compounds and improve the production processes.

References:

- [1] Dufosse, L.; Fouillaud, M.; Caro, Y.; Mapari, S.A.S.; Sutthiwong, N. Filamentous fungi are large-scale producers of pigments and colorants for the food industry. *Current Opinion in Biotechnology* **2014**, *26*, 56-61.
- [2] Montaser, R.; Luesch, H. Marine natural products: A new wave of drugs? *Future Med. Chem.* **2011**, *3*, 1475-1489.
- [3] Caro, Y.; Anamale, L.; Fouillaud, M.; Laurent, P.; Petit, T.; Dufosse, L. Natural hydroxyanthraquinoid pigments as potent food grade colorants: An overview. *Nat. Prod. Bioprospect.* **2012**, *2*, 174-193.
- [4] Fouillaud, M.; Venkatchalam, M.; Girard-Valenciennes, E.; Caro, Y.; Dufosse, L. Anthraquinones and derivatives from marine-derived fungi: Structural diversity and selected biological activities. *Marine Drugs* **2016**, *14*, 64.

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Keywords: red, pigment, anthraquinone, marine, fungi

In industries, authorized red pigments are mainly issued from plants (as lycopene from tomato or betalains from beetroot), cochineal insects (carmine red) or from chemical synthesis. Their uses are more and more questioned with regard to the culture constraints or health problems. New resources for the production of natural red colorants are therefore under focus [1, 2]. Marine-derived fungi are at the forefront in the search of new compounds of interest that could be produced through biotechnology [3]. In the field of colors, the marine-derived microfungi are able to synthesize a wide diversity of pigments/ hues, amongst which red anthraquinones are well represented. Some of their main advantages are they are considered as natural, and their productions are « upscalable » in an industrial point of view. This work highlights the anthraquinoid red pigments known, up to date, from marine-derived fungi. We summarize about thirty compounds produced from about 25 strains that have been discovered in the former years. Beside the widespread *Aspergillus*, *Alternaria*, *Eurotium*, *Fusarium* or *Penicillium*, some original genera as *Halorosellinia*, *Nigrospora*, *Stemphylium* or *Xylaria* were identified as red anthraquinoid molecules's producers. Well known substances such as austrocortinin, catenarin, erythroglaucon or bostrycin were characterized in the fungal productions, as well as several new compounds, never mentioned, up to now, from other organisms. They could interestingly be further studied as potential sources of red colors to be operated in food, cosmetic or dyeing industries. Beside their coloring properties, these compounds sometimes exhibit diverse biological activities such as antimicrobial or anticancer effects, sparsely mentioned in the literature. This aspect, when available, is also documented, in order to examine the potential use of these compounds and to help broadening the horizon of colors with innovative natural substances.

References:

- [1] L. Dufossé, M. Fouillaud, Y. Caro, S.A.S. Mapari, N. Sutthiwong, *Current Opinion in Biotechnology* **26**, (2014), 56-61.
- [2] Y. Caro, L. Anamale, M. Fouillaud, P. Laurent, T. Petit, L. Dufossé, *Natural Products and Bioprospecting* **2**, (2012), 174-193.
- [3] R. Montaser, H. Luesch, *Future Medicinal Chemistry* **3**, (2011), 1475-1489.



8th International Congress „Pigments in Food”



Colored Food for Health Benefits

BOOK of ABSTRACTS

CLAVDIOPOLIS
COLOSWAR *vulgo* CLAVSENBURG
Transilvanie civitas primaria



28th of June – 1st of July 2016
Cluj-Napoca, Romania



8th International Congress
„Pigments in Food”
Colored Food for Health Benefits

BOOK of ABSTRACTS

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Pigments in Food- VIII (2016) in Cluj-Napoca, Romania are dedicated to health benefits!

PREFACE

On behalf of the Organizers of the Eight International Congress PIGMENTS IN FOOD, it is our pleasure to welcome you, at the Department of Chemistry and Biochemistry at the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.

After seven successful Congresses “Pigments in Food”, starting in Sevilla, Spain (1999) and passing through Lisbon, Portugal (2002), Quimper, France (2004), Stuttgart-Hohenheim, Germany (2006), Helsinki, Finland (2008), Budapest, Hungary (2010), and Novara, Italy (2013), we are honored to host this edition, PIF2016 in the capital of Transylvania region, Romania.

It was the best opportunity for scientists from all over the world (17 countries: UK, USA, Germany, France, Reunion Island, Spain, Italy, Denmark, Hungary, Poland, Turkey, Brazil, Uruguay, Panama, Mexico, China and Romania) to show their advances in scientific and technological topics, related to plant pigments and food colorants.

The 6 sessions were well adapted to cover the most important and outstanding directions of research and technology development in this research e.g. chemical characterization and bioprospecting, to advanced bioanalytical methods, (bio)technological production and formulation, pigment processing and stability, bioactivity, functionality and health effects, as well quality and safety aspects.

The program includes 5 plenary lectures and 7 keynote lectures by best international experts in the field, as well as 20 oral presentations and more than 65 poster contributions.

An important aim of PIF2016 is also represented by the opportunity of meeting and discussion for scientists dealing with different aspects of pigments, such as chemists, food chemists, food technologists, biotechnologists, nutritionists, but also industry representatives.

A comprehensive scientific program, adapted to the new approaches and trends in this scientific area was designed and realized – such approach had a particularly strategic aim, to demonstrate that and how pigments and colored food bring health benefits.

We are delighted to offer you, meanwhile, the opportunity to visit the historical city of Cluj-Napoca, to enjoy the traditional food and life in the beautiful Transylvanian landscape and to discover our cultural and academic heritage!

On behalf of the Organizing Committee,

Carmen Socaciu - chair
Adela Pinteau – co-chair

SCIENTIFIC PROGRAM - PIF 2016 at USAMV, Cluj-Napoca

Tuesday June 28 th	Wednesday, June 29 th	Thursday, June 30 th	Friday, July 1 st
	<p>8.00-9.00 Registration</p> <p>9.00-9.45 Plenary lecture 2: Neal Craft 9.45-10.00 Welcome EUCHEMS FCD - Marco Arlorio</p> <p>Session 1A Chemical characterization and Bioprospecting 10.00-10.30 Key note lecture 1: Antonio Meléndez Martínez 10.30-11.00 Oral presentations (15min): Jozsef Deli, Mekala Venkatachalam</p> <p>11.00-11.30: Coffee Break & Poster session</p>	<p>Session 4 Food processing, pigments stability and color development 8.30-9.15 Plenary lecture 5: Monica Giusti 9.15-9.45 Key note lecture 5: Laurent Dufossé 9.45-11.00 Oral presentations (15 min) Kewei Chen, Mihaela Turturică, Miriana Durante, Pu Jing, Marco Arlorio</p> <p>11.00-11.30 Coffee Break & Poster session</p>	<p>Session 6 Quality and safety of food pigments 9.00-9.30 Key note lecture 7: Manfred Eggersdorfer 9.30-10.00 Oral presentations (15min) Michael Murkovic, Antoanela Patras 10.00-10.35 Selected poster presentations (6 x 6 min)</p> <p>10.35-11.15 Coffee Break & Poster session</p>
<p>14.00-18.00 Registration</p> <p>16.30-17.00 Opening Ceremony</p> <p>17.00-17.45 Plenary lecture 1: George Britton</p> <p>17.45-19.00 Poster session</p> <p>19.00 Welcome party</p>	<p>Session 1B Chemical characterization and Bioprospecting 11.30-12.00 Key note lecture 2: Dámaso H.Méndez 12.00-12.30 Oral presentations (15min) Judith Müller-Maatsch, Işıl İtler</p> <p>12.30-13.30 Lunch break</p> <p>13.30-14.00 Poster session 14.00-14.45 Plenary lecture 3: Øyvind Andersen</p> <p>Session 2 Advanced bioanalytical methods 14.45-15.15 Key note lecture 3: Daniele Giuffrida 15.15-15.45 Oral presentations (15min) A. Ligia Focsan, Luis E. Rodriguez-Saona</p> <p>15.45-16.15 Coffee Break & Poster session</p> <p>16:45-17:30 Plenary lecture 4: Gerhard Sandmann</p> <p>Session 3 Emerging (bio)technologies of pigment production and formulation 17.30-18.00 Key note lecture 4: Paul Fraser 18.00-18.30 Oral presentations Philippe Thonart, Stefan Martens</p> <p>20.00 Gala Dinner in Cluj-Napoca</p>	<p>Session 5 Bioactivity, functionality and health effects 11.30-12.00 Key note lecture 6: Begoña Olmedilla-Alonso 12.00-13.15 Oral presentations (15 min) Marta Roca, Flore Depeint, Antonio Pérez-Gálvez, Marcello S. Lenucci, Gábor Palotás</p> <p>13.15-14.15 Lunch break and Poster session</p> <p>14.30 Transylvanian Landscape Trip: from Salt Mine Turda to Coltesti, a typical Transylvania village (including Dinner)</p>	<p>Session 7 Round Table 11.15-12.15 Presentation of EU projects: COST EUROCAROTEN FP-7 DISCOvery PROCAR</p> <p>12.15-13.00 Poster Awards and Closing ceremony 13.00-14.00 Lunch</p> <p>Optional social events: City Tour and concerts at International Festival “Jazz in the Park”</p>

SCIENTIFIC PROGRAMME

INSTITUTE OF LIFE SCIENCES UNIVERSITY OF AGRICULTURAL SCIENCES AND VETERINARY MEDICINE CLUJ-NAPOCA BLUE HALL

28.06.2016. Tuesday

- 14.00-18.00 Registration
16.30-17.00 Opening Ceremony
Chair: Carmen Socaciu
17.00-17.45 **PL1. Reflections from a colour fan.**
George Britton
*University of Liverpool, School of Biological Sciences, Liverpool L69
7ZB, U.K.*
17.45-19.00 Poster session
19.00-21.00 Welcome party

29.06.2016. Wednesday

- 8.00-9.00 Registration
Chair: George Britton - Carmen Socaciu
9.00-9.45 **PL2. Chromatography tool box for the separation of pigments.**
Neal E. Craft
Craft Technologies, Inc., Wilson, NC USA
9.45-10.00 Welcome EUCHEMS FCD
Marco Arlorio
Session 1A Chemical characterization and Bioprospecting
10.00-10.30 K1. Phytoene and phytofluene in the diet and health.
Antonio J. Meléndez-Martínez
*Food Colour & Quality Lab., Department of Nutrition & Food Science,
Universidad de Sevilla Sevilla, Spain*
10.30-10.45 O1. Carotenoid composition and biosynthesis of β -carotenoids in red
mamey (Pouteria Sapota)
József Deli, Erika Turcsi, Attila Agócs, Veronika Nagy, Gergely Gulyás-
Fekete, Enrique Murillo.
*Department of Biochemistry and Medical Chemistry, University of Pécs,
Hungary*
10.45-11.00 O2. Isolation and characterization of pigments from *Talaromyces*
Albobiverticillius: a marine derived fungus producing polyketide red
pigments
Mekala Venkatachalam, Kristian Fog Nielsen, Daniele Giuffrida, Yanis
Caro, Emmanuelle GirardValenciennes, Laurent Dufossé, Mireille
Fouillaud
*Laboratoire de Chimie des Substances Naturelles et des Sciences des
Aliments – LCSNSA EA 2212, Université de la Réunion, 15 Avenue René
Cassin, CS 92003, F-97744 Saint-Denis Cedex 9, Ile de la Réunion,
France*
11.00-11.30 *Coffee Break & Poster session*

Session 1B Chemical characterization and Bioprospecting**Chair: Antonia Melendez Martinez – József Deli**

- 11.30-12.00 K2. Xanthophyll esters: the ugly duckling of the carotenoids.
Dámaso Hornero-Méndez,
Department of Food Phytochemistry, Instituto de la Grasa, Consejo Superior de Investigaciones Científicas (CSIC), Sevilla, Spain
- 12.00-12.15 O3. Characterization and chromoplastidal deposition of carotenoids from gac fruit (*Momordica Cochinchinensis*) arils.
Judith Mueller-Maatsch, Florence Kreiser, Judith Hempel, Oliver Paquet-Durand, Reinhold Carle, Ralf Schweiggert,
University of Hohenheim, Institute of Food Science and Biotechnology, Chair of Plant Foodstuff Technology and Analysis, Garbenstrasse 25, 70599 Stuttgart, Germany
- 12.15-12.30 O4. Extraction of natural colorant; phycocyanin from cyanobacteria *spirulina platensis*.
Işıl İlter, Saniye Akyıl, Mehmet Koç, Zeliha Demirel, Meltem Conk-Dalay, Figen Kaymak-Ertekin,
Faculty of Engineering, Food Engineering Department, Ege University, Bornova-İZMİR
- 12.30-13.30 *Lunch*
- 13.30-14.00 Poster session
- 14.00-14.45 **PL3. Anthocyanins in food - facts and challenges.**
Øyvind M. Andersen
Department of Chemistry, University of Bergen, N-5007 Bergen, Norway

Session 2 Advanced bioanalytical methods**Chair: Paul Fraser - Monica Giusti**

- 14.45-15.15 K3. Application of advanced chromatography methods for the pigments characterization in fresh and overripe fruits and vegetables.
Daniele Giuffrida, Francesco Cacciola, Margita Utczas, Domenica Mangraviti, Ivana Bonaccorsi, Veronica Inferrera, Paola Donato, Paola Dugo, Luigi Mondello,
B.I.O.M.O.R.F. Department, University of Messina, Messina, Italy
- 15.15-15.30 O5. Carotenoid neutral radicals formed by deprotonation of the radical cation: chemical characterization.
A. Ligia Focsan, Lowell D. Kispert
Department of Chemistry, Valdosta State University, Valdosta, Georgia, United States
- 15.30-15.45 O6. Authentication of food pigments by vibrational spectroscopy.
Luis E. Rodriguez-Saona and M. Monica Giusti
Department of FoodScience and Technology, The Ohio StateUniversity, Columbus, OH, USA
- 15.45-16.15 *Coffee Break & Poster session*
- 16:45-17:30 **PL4. Genetic engineering of carotenoid production.**
Gerhard Sandmann,
Molecular Bioscience, Goethe University, Frankfurt/M., Germany

Session 3 Emerging (bio)technologies of pigment production and formulation**Chair: Laurent Dufossé – Adela Pinte**

- 17.30-18.00 K4. Genetic intervention approaches to the enhancement of carotenoid and flavonoids in tomato fruit.
Paul D. Fraser,
Biochemistry, School of Biological Sciences, Egham Hill, Egham, Surrey, TW200EX. UK
- 18.00-18.15 O7. Bioprocessing of anthocyanins extraction from Hibiscus sabdariffa.
CheikBeye, Thami El Mejdoub, Jacqueline Destain and Philippe Thonart,
University of Liege, Gembloux Agro-Bio Tech, Walloon Center for Industrial Biology (CWBI), Passage des Déportés 2, B-5030 Gembloux, Belgium
- 18.15-18.30 O8. From bench to application: ANTHOPLUS – anthocyanin production platform using advanced plant suspension cultures as green cell factories (ERA-IB).
Stefan Martens, Cathie Martin, Ingo Appelhagen, Trine Hvoslef-Eide, Anne Oertel, Doris Marko, Gudrun Pahlke, Hans-Peter Mock, Andrea Matros,
TransMIT Project Division for Plant Metabolites and Chemicals, Germany
- 20.00-23.00 *Gala Dinner – Restaurant Da Vinci*

30.06.2016. Thursday**Session 4****Food processing, pigments stability and color development****Chair: B. Olmedilla Alonso - Marco Arlorio**

- 8.30-9.15 **PL5. Anthocyanin chemical structure affects their stability, bioavailability and functionality in the human body**
Monica Giusti
Food Science and Technology department, The Ohio State University
- 9.15-9.45 K5. Red colorants from filamentous fungi. Are they ready for the food industry?
Laurent Dufossé
Université de La Réunion, LCSNSA Laboratoire de Chimie des Substances Naturelles et des Sciences des Aliments & ESIROI agroalimentaire, F-97490 Saint-Denis, Reunion island, Indian ocean, France
- 9.45-10.00 O9. Chlorophyll catabolites present in the main edible seaweed species.
Kewei Chen, Jose Julián Ríos, Antonio Pérez-Gálvez, María Roca,
Department of Food Phytochemistry, Instituto de la Grasa, Consejo Superior de Investigaciones Científicas (CSIC), Sevilla, Spain
- 10.00-10.15 O10. Characterisation and thermal degradation of anthocyanins from red plums.
Mihaela Turturică, Nicoleta Stănciuc, Gabriela Bahrim, Gabriela Râpeanu,
Dunărea de Jos University of Galati, Faculty of Food Science and Engineering, 111 Domnească Street, 800201, Galati, Romania
- 10.15-10.30 O11. Encapsulation in cyclodextrins of pumpkin and tomato oleoresins extracted by supercritical CO₂.
Miriana Durante, Marcello Salvatore Lenucci, Pier Paolo Marrese, Vito Rizzi, Monica De Caroli, Gabriella Piro, Paola Fini, Giovanni Mita,
Istituto di Scienze delle Produzioni Alimentari, Consiglio Nazionale delle Ricerche (CNR), Lecce, Italy

- 10.30-10.45 O12. Computer simulation and experimental methods to study influence of three phenolic acids on peonidin derivative stability.
Manman Lu, Jianxiong Cai, Wei Xu, Jing Chen, Shujuan Zhao, Pu Jing
Department of Food Science and Engineering, Shanghai Jiao Tong University, Shanghai
- 10.45-11.00 O13. Formation of coloured diaminobenzoquinones from (ethyl)vanillin in bakery products.
M. Arlorio, R. Negri, G. del Favero, J.D. Coisson, V. Papillo, F. Travaglia, V. Gokmen, D. Marko, G.B. Giovenzana.
Dipartimento di Scienze del Farmaco & Drug and Food Biotechnology Center, Università del Piemonte Orientale A. Avogadro, 28100 Novara, Italy
- 11.00-11.30 *Coffee Break & Poster session*
- Session 5**
Bioactivity, functionality and health effects
Chair: Øyvind Andresen - Damaso Hornero-Mendez
- 11.30-12.00 K6. Bioavailability, bioaccessibility and bioconversion of the major provitamin A carotenoids in the human diet.
Begoña Olmedilla-Alonso,
Institute of Food Science, Technology and Nutrition (ICTAN-CSIC), Madrid, Spain
- 12.00-12.15 O14. Bioavailability of chlorophyll derivatives in human epithelial cells.
Kewei Chen, María Roca,
Department of Food Phytochemistry, Instituto de la Grasa, CSIC, Sevilla, Spain
- 12.15-12.30 O15. Hypolipemic activity of astaxanthin supplementation in mice.
Myriam Benarroch, Justine Lallement, Larbi Rhazi, Camille Boroch, Cindy Hugot, Claude-Narcisse Niamba, Hassan Younes, Flore Depeint,
Department of Nutrition and Health Sciences, LaSalle Beauvais Polytechnic Institute, Beauvais, France
- 12.30-12.45 O16. Human colostrum is a pool of carotenoid metabolites. A systematic approach with MS tools.
Antonio Pérez-Gálvez, Juan Garrido-Fernández, José J. Ríos, Adriana Mercadante, Ana A.O. Xavier, Josefa Aguayo Maldonado,
Food Phytochemistry Department, Instituto de la Grasa (CSIC), Sevilla, Spain
- 12.45-13.00 O17. Health turns red: comparative study on supercritical CO₂ extraction of lycopene from fruits and effect of the nanocarrier encapsulated oleoresins on cultured lung adenocarcinoma cells.
Andreina Bruno, Mirana Durante, Elisabetta Pace, Pier Paolo Marrese, Giovanni Mita, Gabriella Piro, Marcello S. Lenucci,
Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali (Di.S.Te.B.A.), Università del Salento, Lecce, Italy
- 13.00-13.15 O18. Development and human clinical study of a new vegetable puree product.
Gábor Palotás, Eszter Sarkadi Nagy, Hussein Daood, Éva Martos, Lajos Helyes, Andrea Lugasi,
Univer Product Zrt., Kecskemét, Hungary

- 13.15-14.15 *Lunch break and Poster session*
14.30-22.00 *Transylvanian Landscape Trip: from Salt Mine Turda to Colțesti, a typical Transylvanian village (including Dinner)*

01.07.2016. Friday

Session 6

Quality and safety of food pigments

Chair: Philippe Thonart - Gerhard Sandmann

- 9.00-9.30 K7. Perspectives in innovation in food pigments – An industry view.
Manfred Eggersdorfer, Ulrich Killeit, Dirk Cremer,
DSM Nutritional Products, Kaiseraugst, Switzerland
- 9.30-9.45 O19. Oxidation of edible oils in presence of carotenes and xanthophylls.
Michael Murkovic, Alam Zeb, Marini Damanik,
Graz University of Technology, Institute of Biochemistry, Functional Food Group, Petersgasse 12/2, 8010 Graz, Austria
- 9.45-10.00 O20. Colour evaluation and antioxidant activity of red cabbage extract in presence of different additives.
Antoanela Patras, Razvan Filimon.
Department of Sciences, Faculty of Horticulture, University of Agricultural Sciences and Veterinary Medicine „Ion Ionescu de la Brad”, Iasi, Romania
- 10.00-10.35 Selected poster presentations
- 10.35-11.15 *Coffee Break & Poster session*

Session 7

Round Table

- 11.15-12.15 Presentation of EU projects: COST EUROCAROTEN, FP-7 DISCOvery and PROCAR
O21. From DISCOvery to products: A next generation pipeline for the sustainable generation of high-value plant products
The DISCO consortium (coordinator Paul D. Fraser)
Biochemistry, School of Biological Sciences, Royal Holloway University of London, Egham Hill, Egham, Surrey, TW20 OEX. UK
O22. Cost action EUROCAROTEN (European network to advance carotenoid research and applications in agro-food and health, CA15136)
Antonio J. Meléndez-Martínez
Food Colour & Quality Lab., Department of Nutrition & Food Science, Universidad de Sevilla, Seville, Spain.
O23. PROCAR: the exploitation of *Xanthophyllomyces Dendrorhous* as a sustainable platform for the production of high-value carotenoids, an ERA-IB-14-073 project.
Gerhard Sandmann,
Biosynthesis Group, Molecular Biosciences, Goethe University Frankfurt, Frankfurt, Germany
- 12.15-13.00 Poster Awards and Closing ceremony
- 13.00-14.00 *Lunch*

List of Posters

Session 1 **Chemical characterization and Bioprospecting**

1

- P1-1 Far UV peak contributes to the identification of E/Z isomers of carotenoids.
Enrique Murillo,
Laboratorio de Bioquímica de Alimentos y Nutrición, Universidad de Panamá, Panamá, Panamá
- P1-2 Isolation of allene carotenoids from mamey.
Attila Agócs, Enrique Murillo, Erika Turcsi, Szabolcs Béni, András Darcsi, József Deli
Department of Biochemistry and Medical Chemistry, University of Pécs, Hungary
- P1-3 Evaluation of bioactive compounds in fermented black table olives.
Miriana Durante, Maria Tufariello, Luca Tommasi, Gianluca Bleve, Giovanni Mita
Istituto di Scienze delle Produzioni Alimentari, Consiglio Nazionale delle Ricerche (CNR), Lecce, Italy
- P1-4 Anthocyanins composition of jaboticaba and pitanga from different cities of Brazil
Anna Rafaela Braga, Katia Biazotto, Veridiana Vera de Rosso,
Biosciences Department, Federal University of São Paulo, Santos - São Paulo, Brazil
- P1-5 Carotenoid composition of four Brazilian fruits from Atlantic forest and cerrado.
Kátia Regina Biazotto, Anna Rafaela Cavalcante Braga, Veridiana Vera de Rosso,
Biosciences Department, Federal University of São Paulo, Santos - São Paulo, Brazil
- P1-6 Black as a tomato: the anthocyanin-synthesizing tomato genotype 'Sun BlackTM'
F. Blando, H. Berland, M. Durante, C. Gerardi, A. Mazzucato, G. Mita, Ø M Andersen
Institute of Sciences of Food Production - Lecce section Italian National Research Council (CNR), Lecce- Italy
- P1-7 Reduction of decarboxylated derivatives of betacyanin pigments.
Dominika Szot, Sławomir Wybraniec,
Department of Analytical Chemistry, Institute C-1, Faculty of Chemical Engineering and Technology, Cracow University of Technology, Cracow, Poland
- P1-8 Oxidation of hydrogenated derivatives of betanin.
Dominika Szot, Sławomir Wybraniec,
Department of Analytical Chemistry, Institute C-1, Faculty of Chemical Engineering and Technology, Cracow University of Technology, Cracow, Poland
- P1-9 Anthocyanin-rich extract from Italian black rice (*Var. Artemide*) as functional ingredient for bakery products.
Monica Locatelli, Valentina Azzurra Papillo, Fabiano Travaglia, Jean Daniel Coisson and Marco Arlorio
Dipartimento di Scienze del Farmaco & Drug and Food Biotechnology Center, Università degli Studi del Piemonte Orientale, Novara, Italy

- P1-10 Application of progressive pearling process to anthocyanins rich wheat cultivars to obtain pigmented ingredients.
Monica Locatelli, Valentina A. Papillo, Stefania Monteduro, Fabiano Travaglia, Debora Giordano, Amedeo Reyneri, Massimo Blandino, Marco Arlorio, Jean Daniel Coisson,
Dipartimento di Scienze del Farmaco, Università del Piemonte Orientale “A. Avogadro”, Novara, Italy
- P1-11 Carotenoid glycoside isolated and identified from cyanobacterium *Cylindrospermopsis raciborskii*.
Veronika Nagy, Attila Agócs, József Deli, Gergely Gulyás-Fekete, Tünde-Zita Illyés, Erika Turcsi, Gábor Vasas,
Department of Biochemistry and Medical Chemistry, University of Pécs, Pécs, Hungary
- P1-12 Extraction of fungal polyketide pigments using ionic liquids.
Juliana Lebeau, Mekala Venkatachalam, Mireille Fouillaud, Laurent Dufossé and Yanis Caro,
University of La Réunion, LCSNSA & ESIROI Saint-Denis, Reunion Island, Indian ocean, France
- P1-13 Marine-derived fungi producing red anthraquinones: new resources for natural colors?
Mireille Fouillaud, Mekala Venkatachalam, Yanis Caro, and Laurent Dufossé,
Laboratoire de Chimie des Substances Naturelles et des Sciences des Aliments – LCSNSA EA2212, Université de la Réunion, Saint-Denis, Ile de la Réunion, France
- P1-14 Distribution and evolution of phenolic compounds in skins and seeds of different grape varieties.
Elisabeta-Irina Geană, Alexandru Ciocârlan,
National R&D Institute for Cryogenics and Isotopic Technologies – ICIT Rm. Valcea, 4th Uzinei Street, PO Raureni, Box 7, 240050 Rm. Valcea, Romania
- P1-15 Phenolic profile and antioxidant properties of functional foods based on honey and dry fruits.
Elisabeta-Irina Geană, Cornelia Dostetan,
National R&D Institute for Cryogenics and Isotopic Technologies – ICIT Rm. Valcea, 4th Uzinei Street, PO Raureni, Box 7, 240050 Rm. Valcea, Romania
- P1-16 Optimization of fermentation conditions for fungal growth and production of red pigments from *Talaromyces albobiverticillius* using response surface methodology.
Mekala Venkatachalam, Alain Shum Cheong Sing, Yanis Caro, Laurent Dufossé, Mireille Fouillaud,
Laboratoire de Chimie des Substances Naturelles et des Sciences des Aliments – LCSNSA EA 2212, Université de la Réunion, 15 Avenue René Cassin, CS 92003, F-97744 Saint-Denis Cedex 9, Ile de la Réunion, France
- P1-17 Bacterial carotenoid production of antarctic isolates.
María Eugenia Vila, Gastón Azziz, Silvia Batista, Verónica Saravia,
Bioengineering Department, Chemical Engineering Institute, Engineering Faculty, Universidad de la República, Montevideo, Uruguay.
- P1-18 Potential of chromosomes 7D and 7D^{ch} for the enhancement of lutein esterification in wheat.
Maria G. Mattera, Adoración Cabrera, Dámaso Hornero-Méndez, Sergio G. Atienza,
Department of Food Phytochemistry, Instituto de la Grasa (CSIC), Campus Universidad Pablo de Olavide, Edificio 46, Ctra. de Utrera, Km 1, E-41013 Sevilla, Spain

- P1-19 Identification and quantification of anthocyanins in wild berries by HPLC-PDA-ESI-MS.
Zorița Diaconeasa, Dumitrița Rugină, Loredana F. Leopold, Andrea Bunea, Andreea Stănilă, Carmen Socaciu,
Department of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania

Session 2 Advanced bioanalytical methods

2

- P2-1 Structural characterization of chlorophyll derivatives.
 Antonio Perez-Gálvez, K. Chen, José Julián Ríos, María Roca,
Department of Food Phytochemistry, Instituto de la Grasa, CSIC, Sevilla, Spain
- P2-2 Separation of mamey (*Pouteria sapota*) carotenoid epoxide diastereomers on chiral stationary phase.
Erika Turcsi, Tibor Kurtán, Enrique Murillo, Veronika Nagy, József Deli,
Department of Biochemistry and Medical Chemistry, University of Pécs, Pécs, Hungary
- P2-3 A solid-phase extraction method for reducing matrix effect on the MSⁿ analysis of xanthophyll esters.
Ana A.O. Xavier, Juan Garrido-Fernández, José J. Ríos, Antonio Pérez-Gálvez,
Laboratório de Química de Alimentos, DCA - FEA – UNICAMP Campinas, São Paulo - Brasil
- P2-4 Thin layer chromatography (TLC) separation combined with RAMAN mapping for carotenoid identification.
Loredana Florina Leopold, Cristina Coman, Zorita Diaconeasa, Nicolae Leopold, Carmen Socaciu,
Faculty of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine, Mănăștur 3-5, 400372 Cluj-Napoca, Romania
- P2-5 Raman imaging of norbixin after cellular internalization in D407 RPE cells.
Cristina Coman, Loredana Florina Leopold, Olivia Dumitrița Rugină, Zorița Diaconeasa, Oana Lelia Pop, Maria Tofană, Carmen Socaciu, Adela Pinteau, Nicolae Leopold,
Faculty of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania

Session 3 Emerging (bio)technologies of pigment production and formulation

3

- P3-1 Emerging greener extraction systems for fungal pigments isolation.
 Juliana Lebeau, Mekala Venkatachalam, Mireille Fouillaud, Laurent Dufossé and Yanis Caro,
University of Reunion Island, LCSNSA & ESIROI, Saint-Denis, Reunion Island, Indian ocean, France.
- P3-2 Identification of chlorophyll profile in *Phormidium utumnale* biomass.
Leila Queiroz Zepka, Gabriela P. Nogara, Andressa S. Fernandes, Daniele B. Rodrigues, Adriana Z. Mercadante, Eduardo Jacob-Lopes,
Department of Food Technology and Science, University Federal of Santa, Santa Maria, Brazil
- P3-3 The bioeconomy of carotenoid-rich oleoresins produced in microalgal biorefineries.
Eduardo Jacob-Lopes, Tatiele Casagrande do Nascimento, Leila Queiroz Zepka,
Department of Food Technology and Science, Federal University of Santa Maria, Brazil

- P3-4 Carotenoid profile and antioxidant capacity of three microalgae species.
Eduardo Jacob-Lopes, Tatiele Casagrande do Nascimento, Luciana Dapieve Patias, Andressa Fernandes, Leila Queiroz Zepka,
Department of Technology and Food Science, Federal University of Santa Maria-RS, Brazil
- P3-5 Bioconversion of anthocyanins from jussara pulp by *Lactobacillus* and *Bifidobacterium*.
Anna Rafaela Braga, Veridiana Vera de Rosso,
Biosciences Department, Federal University of São Paulo, Santos - São Paulo, Brazil
- P3-6 New and sustainable carotenoid extraction from tomatoes for food industry.
Paula Martins, Veridiana de Rosso,
Departamento Bioscience, Federal University of São Paulo, Baixada Santista, Brazil
- P3-7 Carotenoid-rich microspheres and microcapsules: comparative efficiency of encapsulation, stability and delivery *in vitro* (simulated gastric and intestinal media).
F. Romanciuc, A. Lazar, F. Csernaton, C. Socaciu,
*University of Agricultural Sciences and Veterinary Medicine
RTD Centre for Applied Biotechnology, Proplanta SRL*
- P3-8 Zeaxanthin production by *Antarctic Flavobacterium* Sp..
María Eugenia Vila, Alejandra Rodriguez, Verónica Saravia,
Bioengineering Department, Chemical Engineering Institute, Engineering Faculty, Universidad de la República, Montevideo, Uruguay
- P3-9 A metabolite profiling approach to the characterisation of new colour mutants in *Xanthophyllomyces dendrorhous*.
Eugenio Alcalde, Thunazzina Ali and Paul D Fraser,
School of Biological Science, Royal Holloway University of London, Egham, TW20 0EX, UK
- P3-10 Phenolic compounds, flavonoids, carotenoids and antioxidant capacity of apricot (*Prunus armeniaca* L.) pomace fermented by two filamentous fungi in solid state system.
Francisc V. Dulf, Dan C. Vodnar, Andrea Bunea, Adela Pinte, Carmen Socaciu,
Department of Environmental and Plant Protection, University of Agricultural Sciences and Veterinary
- P3-11 Microwave effect on free and encapsulated, with or without sea buckthorn, *Lactobacillus casei* ATCC 393 in yoghurt.
Oana Lelia Pop, Francisc Dulf, Lucian Cuiabus, Dan Cristian Vodnar, Cristina Coman, Carmen Socaciu, Ramona Suharoschi,
Department of Food Science, University of Agricultural Science and Veterinary Medicine Cluj-Napoca, Romania
- P3-12 Carotenoid production by *Blaskelea trispora* on crude glycerol media.
Vodnar Dan Cristian, Francisc Vasile Dulf, Alexandru Rusu, Trif Monica, Pop Oana Lelia, Socaci Sonia, Carmen Socaciu,
Department of Food Science and Technology, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania

Session 4 Food processing, pigments stability and color development

- P4-1 Evaluation of color stability of the non-genotoxic purple pigment from *Peltogyne mexicana* heartwood as a colorant for yoghurt and gelatin products.
Paulina Gutiérrez, Cinthya Gutiérrez, Leticia Garduño, Myriam Arriaga,
Blanca Barragán,
Department of Environmental Systems Engineering, Instituto Politécnico Nacional, México City, Mexico

- P4-2 Stability of betalain from *Stenocereus pruinosus* fruit as a yellow-orange colorant for gummies and model beverages.
Juan A. Rodríguez-Sánchez, Blanca E. Barragán-Huerta,
Department of Environmental Systems Engineering. Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, Av. Wilfrido Massieu, Unidad Profesional Adolfo López Mateos, D.F. 07738, Mexico
- P4-3 Influence of olive fruit stones on changes and transfer of chlorophyll pigments during virgin olive oil elaboration.
Honorio Vergara-Domínguez, María Roca and Beatriz Gandul-Rojas,
Chemistry and Biochemistry Pigment Group, Food Phytochemistry Department, Instituto de la Grasa (CSIC), Sevilla, Spain
- P4-4 Changes and transfer of chlorophyll pigments during virgin olive oil elaboration from heat-treated fruits.
Honorio Vergara-Domínguez, María Roca and Beatriz Gandul-Rojas B.
Chemistry and Biochemistry Pigment Group, Food Phytochemistry Department, Instituto de la Grasa (CSIC), Sevilla, Spain
- P4-5 Pigment changes during preservation of green table olive specialities treated with alkali and without fermentation: effect of thermal treatments and storage conditions.
Beatriz Gandul-Rojas, Lourdes Gallardo-Guerrero,
Chemistry and Biochemistry Pigment Group, Food Phytochemistry Department, Instituto de la Grasa (CSIC), Sevilla, Spain
- P4-6 Development of carrots with high pigmentation for natural food colors.
Sabine Karin Clausen, Søren Kjærsgaard Rasmussen,
University of Copenhagen, Faculty of Science, Department of Plant and Environmental Sciences, Section for Plant and Soil Science, Molecular Plant Breeding Group, Thorvaldsensvej 40, 1871 Frederiksberg C, Denmark
- P4-7 Anthocyanin and phenolic profile of red wines obtained from Karalahna grapes, a native grape variety of Bozcaada (Tenedos), Turkey
Burcu Şişli, Nesrin Merve Çelebi, Aslı Bayhan, Ayşegül Kırca Toklucu,
Department of Food Engineering, Faculty of Engineering, Çanakkale Onsekiz Mart University, Çanakkale, Turkey
- P4-8 Effect of spontaneous and inoculated fermentations on anthocyanins and phenolics of Cabernet Sauvignon wines.
Nesrin Merve Çelebi, Burcu Şişli, Aslı Bayhan, Ayşegül Kırca Toklucu,
Department of Food Engineering, Faculty of Engineering, Çanakkale Onsekiz Mart University, Çanakkale, Turkey
- P4-9 The effect of physical form of *Phaeodactylum tricornutum* biomass on fucoxanthin extraction.
Saniye Akyıl, Işıl İlter, Mehmet Koç, Zeliha Demirel, Ayşegül Şeker-
 Erdoğan, Meltem Conk- Dalay, Figen Kaymak-Ertekin,
Food Engineering Department, Faculty of Engineering, Ege University, Bornova-IZMIR- TURKEY
- P4-10 Juice processing effects on quality of aronia pomace—a resource for colour extraction.
Michael Vagiri and Martin Jensen,
Department of Food Science, Aarhus University, Kirstinebjergvej 10, DK-5792, Årslev, Denmark
- P4-11 Spectral and colorimetric characteristics of metal chelates of acylated cyanidin derivatives.
Gregory T. Sigurdson, Rebecca Robbins, Thomas Collins, M. Mónica Giusti
The Ohio State University, Dept. of Food Science and Technology, 2015 Fyffe Ct., Columbus, OH 43210-1007, United States

- P4-12 The influence of copigmentation, pH and ionic force on the antioxidant activity and colour parameters of chokeberry (*Aronia melanocarpa*) extract.
Elena Cristea, Rodica Sturza, Marius Niculaua, Aliona Ghendov-Moşanu, Antoanela Patras,
Department of Sciences, Faculty of Horticulture, University of Agricultural Sciences and Veterinary Medicine „Ion Ionescu de la Brad”, Iasi, Romania
- P4-13 Anthocyanins thermal degradation in sour cherry extract on fluorescence spectroscopy and kinetic modeling basis.
Ana Maria Oancea, Florentina Mihaela Ursache, Gabriela Râpeanu and Nicoleta Stănciuc,
Dunărea de Jos University of Galati, Faculty of Food Science and Engineering, Domnească Street 111, 800201, Galati, Romania
- P4-14 Thermal degradation of the total carotenoid content and antioxidant activity of sea buckthorn (*Hippophae rhamnoides L.*)– A kinetic study.
Florentina Mihaela Ursache, Ana Maria Oancea, Gabriela Râpeanu and Nicoleta Stănciuc,
Dunărea de Jos University of Galati, Faculty of Food Science and Engineering, Domnească Street 111, 800201, Galati, Romania
- P4-15 Thermal degradation kinetics of anthocyanins extracted from anthocyanins extracted from sweet cherries.
Mihaela Turturică, Nicoleta Stănciuc, Gabriela Bahrim, Gabriela Râpeanu, Dunărea de Jos University of Galati, Faculty of Food Science and Engineering, 111 Domnească Street, 800201, Galati, Romania
- P4-16 Identification and quantification of carotenoids presents in Brazilian peppers compared to other varieties.
José Fernando Rinaldi Alvarenga, Paola Andressa Schurachio, Maria Terezinha Silva Bonifácio, Célia Maria Sylos,
Department of Food Science and Nutrition, School of Pharmaceutical Science, UNESP, Araraquara, SP, Brazil
- P4-17 Lipophilic antioxidant capacity, color proprieties and carotenoid content of peppers cultivated in Brazil.
José Fernando Rinaldi Alvarenga, Paola Schurachio, Maria Terezinha Silva Bonifácio, Célia Maria Sylos,
Department of Food Science and Nutrition, School of Pharmaceutical Science, UNESP, Araraquara, SP, Brazil
- P4-18 Stability of carotenoids in frozen and dried sea buckthorn (*Hippophae Rhamnoides L.*) berries.
Elena Andreea Pop, Andrea Bunea, Adela Pinteau,
Department of Chemistry and Biochemistry, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania
- P4-19 The variation of chlorophylls, carotenoids and antioxidant activity in fresh, frozen and dried aromatic plants.
Sanda Andrei, Andrea Bunea, Constantin Bele, Adela Pinteau,
Department of Biochemistry, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania

Session **Bioactivity, functionality and health effects**

5

- P5-1 New approach for pigment metabolomics studies.
María Roca, José Julián Ríos, Antonio Pérez-Gálvez,
Department of Food Phytochemistry, Instituto de la Grasa, CSIC, Sevilla, Spain.

- P5-2 Intervention with different doses of oleaginous extracts of *Tagetes* or kale: effects on lutein content in plasma, lipophilic antioxidant capacity and macular pigment optical density.
Carina Holzwarth, Lara Schubert, Kai Wildner, Volker Böhm,
Institute of Nutrition, Friedrich Schiller University Jena, Jena, Germany
- P5-3 Identification of main dietary sources of polyphenols and assessment of consumption frequency of polyphenol-rich foods and beverages in a typical sample of Romanian adult population.
Iris-Lisbeth Müller, Elena Rakosy-Tican,
Doctoral School of Integrative Biology, Babeş-Bolyai University, Cluj-Napoca, Romania
- P5-4 Chemistry of fungi in chemistry classes of lower and upper secondary level.
Farina Bunjes, Martin Rühl, Verena Pietzner, Holger Zorn, Peter Fleischmann,
Chemistry Education, Institute of Chemistry, Oldenburg University, Oldenburg, Germany
- P5-5 Pigments in blueberries (*Vaccinium myrtilloides* L.) and sea buckthorn (*Hippophae rhamnoides* L.) used in the treatment of diabetes.
Dana Pusta, Roman Morar, Alexandra Pusta,
Department of Animal Productions and Food Safety, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania
- P5-6 Technological strategies for the use of watermelon as a source of bioactive molecules and antioxidant pigments.
Marcello S. Lenucci, Stefania Grassi, Pier Paolo Marrese, Anna Montefusco,
Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali (Di.S.Te.B.A.), Università del Salento, Lecce, Italy
- P5-7 Green vegetables may not be the most important determinant of macular pigment optical density: a study of food source and colour in Spanish subjects.
Rocío Estévez-Santiago, Begoña Olmedilla-Alonso, Beatriz Beltrán-de-Miguel, Carmen Cuadrado-Vives,
Institute of Food Science, Technology and Nutrition (ICTAN-CSIC), Madrid (Spain)
- P5-8 Lupines as model for teaching sustainable food production.
Jutta Honkomp, Michael Schott, Peter Eisner, Verena Pietzner,
Chemistry Education, Institute of Chemistry, Oldenburg University, Oldenburg, Germany
- P5-9 Bioaccessibility of phytoene and phytofluene from fruit and vegetable juices as compared to other carotenoids.
Paula Mapelli-Brahm, Joana Corte-Real, Antonio J. Meléndez-Martínez,
Torsten Bohn,
Food Colour & Quality Lab., Dpt. of Nutrition & Food Science, Universidad de Sevilla, Seville, Spain
- P5-10 Elderberry-derived anthocyanins induce apoptosis and inhibit cell proliferation in melanoma cells.
Rugină Dumitrița, Hanganu Dana, Diaconeasa Zorița, Coman Cristina, Leopold Loredana, Bunea Andrea, Pinteada Adela,
Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania

Session Quality and safety of food pigments

6

- P6-1 Infogest *in vitro* digestion method adapted to carotenoids.
Daniele B. Rodrigues, Lilian R. B. Mariutti, Ana Augusta O. Xavier, Adriana Z. Mercadante,
Department of Food Science, University of Campinas, São Paulo, Brazil
- P6-2 Marigold: much more than lutein esters.
Daniele B. Rodrigues, Adriana Z. Mercadante, Lilian R. B. Mariutti
Department of Food Science, University of Campinas, São Paulo, Brazil

Agócs Attila	16, 41, 50	Cremer Dirk	14
Akyıl Saniye.....	19, 84	Cristea Elena.....	87
Alcalde Eugenio.....	72	Csertatoni F.....	70
Ali Thunazzina.....	72	Cuadrado-Vives Carmen.....	101
Andersen Øyvind M.....	4, 45	Cuibus Lucian.....	74
Andrei Sanda.....	94	Damanik Marini.....	34
Appelhagen Ingo.....	23	Daood Hussein.....	33
Arlorio Marco.....	28, 48, 49	Darcsi András.....	41
Arriaga Myriam.....	76	De Caroli Monica.....	26, 100
Atienza Sergio G.....	57	De Rosso Veridiana Vera	43, 44, 68, 69
Azziz Gastón.....	56	Del Favero G.....	28
Bahrim Gabriela.....	25, 90	Deli József.....	16, 41, 50, 60
Barragán Blanca.....	76	Demirel Zeliha.....	19, 84
Batista Silvia.....	56	Depeint Flore.....	30
Bayhan Aslı.....	82, 83	Destain Jacqueline.....	22
Bele Constantin.....	94	Diaconeasa Zorita.....	58, 62, 63, 104
Beltrán-de-Miguel Beatriz.....	101	Donato Paola.....	10
Benarroch Myriam.....	30	Dostetan Cornelia.....	54
Béni Szabolcs.....	41	Dufossé Laurent.....	12, 17, 51, 52, 55, 64
Berland H.....	45	Dugo Paola.....	10
Beye Cheik.....	22	Dulf Francisc Vasile.....	73, 74, 75
Blandino Massimo.....	49	Durante Miriana.....	45, 32, 26, 42, 100
Blando F.....	45	Eggersdorfer Manfred.....	14
Bleve Gianluca.....	42	Eisner Peter.....	102
Böhm Volker.....	96	El Mejdoub Thami.....	22
Bohn Torsten.....	103	Estévez-Santiago Rocío.....	101
Bonaccorsi Ivana.....	10	Filimon Razvan.....	35
Boroch Camille.....	30	Fini Paola.....	26
Britton George.....	2	Fleischmann Peter.....	98
Bruno Andreina.....	32	Focsan A. Ligia.....	20
Bunea Andrea.....	58, 73, 93, 94, 104	Fog Nielsen Kristian.....	17
Bunjes Farina.....	98	Fouillaud Mireille.....	17, 51, 52, 55, 64
Cabrera Adoración.....	57	Fraser Paul D.....	11, 36, 38, 72
Cacciola Francesco.....	10	Gallardo-Guerrero Lourdes.....	80
Cai Jianxiang.....	27	Gandul-Rojas Beatriz.....	78, 79, 80
Carle Reinhold.....	18	Garduño Leticia.....	76
Caro Yanis.....	17, 51, 52, 55, 64	Garrido-Fernández Juan.....	31, 61
Cavalcante Braga Anna Rafaela.....	43, 44, 68	Geană Elisabeta-Irina.....	53, 54
Chen Jing.....	27	Gerardi C.....	45
Chen Kewei.....	24, 29, 59	Ghendov-Moşanu Aliona.....	87
Cheong Sing Alain Shum.....	55	Giordano Debora.....	49
Ciocârlan Alexandru.....	53	Girard-Valenciennes Emmanuelle.....	17
Clausen Sabine Karin.....	81	Giuffrida Daniele.....	10, 17
Coisson J.D.....	28	Giusti M. Mónica.....	6, 21, 86
Coisson Jean Daniel.....	48, 49	Gokmen V.....	28
Collins Thomas.....	86	Grassi Stefania.....	100
Coman Cristina.....	62, 63, 74, 104	Gulyás-Fekete Gergely.....	16, 50
Conk-Dalay Meltem.....	19, 84	Gutiérrez Cinthya.....	76
Corte-Real Joana.....	103	Gutiérrez Paulina.....	76
Craft Neal E.....	3	Hanganu Dana.....	104

Helyes Lajos.....	33	Müller Iris-Lisbeth.....	97
Hempel Judith.....	18	Murillo Enrique.....	16, 40, 41, 60
Holzwarth Carina.....	96	Murkovic Michael.....	34
Honkomp Jutta.....	102	Nagy Eszter Sarkadi.....	33
Hornero-Méndez Dámaso.....	9, 57	Nagy Veronika.....	16, 50, 60
Hugot Cindy.....	30	Negri R.....	28
Hvoslef-Eide Trine.....	23	Niamba Claude-Narcisse.....	30
Illyés Tünde-Zita.....	50	Niculaua Marius.....	87
İlter Işıl.....	19, 84	Oancea Ana Maria.....	88, 89
Inferrera Veronica.....	10	Oertel Anne.....	23
Jensen Martin.....	85	Olmedilla-Alonso Begoña.....	13, 101
Jing Pu.....	27	Pace Elisabetta.....	32
Kaymak-Ertekin Figen.....	19, 84	Pahlke Gudrun.....	23
Killeit Ulrich.....	14	Palotás Gábor.....	33
Kispert Lowell D.....	20	Papillo A. Valentina.....	48, 49
Koç Mehmet.....	19, 84	Papillo V.....	28
Kreiser Florence.....	18	Paquet-Durand Oliver.....	18
Kurtán Tibor.....	60	Patras Antoanela.....	35, 87
Lallement Justine.....	30	Pérez-Gálvez Antonio...24, 31, 59, 61, 95	
Lazar A.....	70	Pietzner Verena.....	98, 102
Lebeau Juliana.....	51, 64	Pintea Adela.....	63, 73, 93, 94, 104
Lenucci Marcello Salvatore...26, 32, 100		Piro Gabriella.....	26, 32, 100
Leopold Loredana Florina..58, 62, 63,104		Pop Elena Andreea.....	93
Leopold Nicolae.....	62, 63	Pop Oana Lelia.....	63, 74, 75
Locatelli Monica.....	48, 49	Pusta Alexandra.....	99
Lu Manman.....	27	Pusta Dana.....	99
Lugasi Andrea.....	33	Rakosy-Tican Elena.....	97
Maldonado Josefa Aguayo.....	31	Râpeanu Gabriela.....	25, 88, 89, 90
Mangraviti Domenica.....	10	Rasmussen Søren Kjærsgaard.....	81
Mapelli-Brahm Paula.....	103	Regina Biazotto Katia.....	43, 44
Mariutti Lilian R. B.....	105, 106	Reyneri Amedeo.....	49
Marko D.....	28	Rhazi Larbi.....	30
Marko Doris.....	23	Rinaldi Alvarenga José Fernando...91, 92	
Marrese Pier Paolo.....	26, 32, 100	Ríos Jose Julián.....	24, 31, 59, 61, 95
Martens Stefan.....	23	Rizzi Vito.....	26
Martin Cathie.....	23	Robbins Rebecca.....	86
Martins Paula.....	69	Roca María.....	24, 29, 59, 78, 79, 95
Martos Éva.....	33	Rodrigues Daniele B.....	105, 106
Matros Andrea.....	23	Rodriguez Alejandra.....	71
Mattera Maria G.....	57	Rodríguez-Sánchez Juan A.....	77
Mazzucato A.....	45	Rodriguez-Saona Luis E.....	21
Meléndez-Martínez Antonio J. .8, 37, 103		Romanciuc F.....	70
Mercadante Adriana Z.....	31, 105, 106	Rugină Dumitrița.....	58, 63, 104
Merve Çelebi Nesrin.....	82, 83	Rühl Martin.....	98
Mita G.....	32, 45	Rusu Alexandru.....	75
Mita Giovanni.....	26, 42, 32, 100	Sandmann Gerhard.....	5, 38
Mock Hans-Peter.....	23	Saravia Verónica.....	56, 71
Mondello Luigi.....	10	Schott Michael.....	102
Monteduro Stefania.....	49	Schubert Lara.....	96
Montefusco Anna.....	100	Schurachio Paola Andressa.....	91
Morar Roman.....	99	Schurachio Paola.....	92
Mueller-Maatsch Judith.....	18	Schweiggert Ralf.....	18

Sigurdson Gregory T.....	86
Silva Bonifácio Maria Terezinha	91, 92
Şişli Burcu.....	82, 83
Socaci Sonia.....	75
Socaciu Carmen	58, 62, 63, 70, 73,74, 75
Stănciuc Nicoleta	25, 88, 89, 90
Stănilă Andreea	58
Sturza Rodica	87
Suharoschi Ramona	74
Sylos Célia Maria.....	91, 92
Szot Dominika	46, 47
Thonart Philippe.....	22
Tofană Maria.....	63
Toklucu Ayşegül Kirca	82, 83
Tommasi Luca	42
Travaglia Fabiano	28, 48, 49
Trif Monica	75
Tufariello Maria	42
Turcsi Erika.....	16, 41, 50, 60
Turturică Mihaela.....	25, 90
Ursache Florentina Mihaela	88, 89
Utczas Margita	10
Vagiri Michael	85
Vasas Gábor.....	50
Venkatachalam Mekala	17, 51, 52, 55, 64
Vergara-Domínguez Honorio	78, 79
Vila María Eugenia	56, 71
Vodnar Dan Cristian	73, 74, 75
Wildner Kai.....	96
Wybraniec Sławomir	46, 47
Xavier Ana A.O.	31, 61, 105
Xu Wei	27
Younes Hassan.....	30
Zeb Alam	34
Zhao Shujuan	27
Zorn Holger.....	98

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