Pigments produced by the bacteria belonging to the genus *Arthrobacter*

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INTRODUCTION

For several decades, pigments have been used as a taxonomic tool for the identification and classification of bacteria. Nowadays, pigment producing microorganisms attract wide interest in many scientific disciplines because of their biotechnological potential. With the growing concern in microbial pigments because of factors such as production independent from seasons and geographical conditions, novel combinations of microorganisms and pigments that can be extracted from the biomass or the culture medium are being evaluated.

The genus *Arthrobacter* is one among the most diverse microbial groups which have been found to produce pigments. Most of bacteria in this genus produce a range of pigments with orange, yellow, blue, green or red hues. At the present time, 80 species in this genus have been accepted by taxonomists. However, the purification and characterization of pigments produced by bacteria belonging to the genus *Arthrobacter* have not been frequently conducted up to the complete description of the chemical structures and the role(s) of pigments in these strains.

Carotenoids

Two psychrophilic bacteria, *Arthrobacter glacialis* and *Arthrobacter flavus* sp. nov., have been discovered as yellow pigments producers. Their pigments were characterized as three C_{50} –carotenoids with molecular formula $C_{50}H_{72}O_2$ (Fig. 2). More recently, *Arthrobacter arilaitensis*, one of the major bacterial species found at the surface of smear-ripened cheeses, has been reported as a yellow pigment producer, pigments which were tentatively identified as carotenoids. Furthermore, the carotenoids excreted by this strain may also belong to the C_{50}-subfamily.

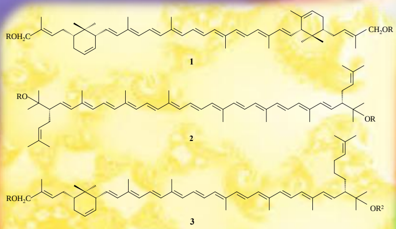


Fig. 2. Chemical structures of carotenoids produced by *Arthrobacter glacialis*. **1.** a: R = H; b: R = Ac. **Derivatized 2**. a: R = H; b: R = $SiMe_3$. **Derivatized 3.** a: R = R^2 = H; b: R = Ac, R^2 = H; c: R = Ac, R^2 = $SiMe_3$.

Riboflavin

Arthrobacter globiformis isolated from soil excreted a yellow pigment during exponential growth, pigment which was identified as riboflavin, $C_{17}H_{20}N_4O_6$, also known as vitamin B2 (Fig. 1)

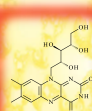
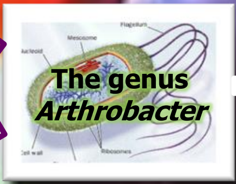


Fig. 1. Chemical structure of riboflavin



Indigoidine

Brilliant blue in color and water-insoluble pigments produced by *Arthrobacter atrocyaneus* and *Arthrobacter polychromogenes* were identified as indigoidine and its derivatives (Fig. 3)

Another strain which produces a blue pigment related to indigoidine is *Arthrobacter crytallopoietes*, although colonies of this *Arthrobacter* appear brilliant green in color. The strain *Arthrobacter oxydans* has been also reported that it produces the blue pigment which is also related to indigoidine.

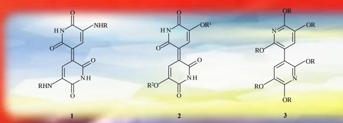


Fig. 3. Chemical structures of indigoidine and its derivatives produced by *Arthrobacter* species. **1.** a: R = H; b: R = CH_3CO. **2.** a: R^1 = R^2 = H; b: R^1 = R^2 = CH_3CO; c: R^1 = R^2 = CH_3; d: R^1 = H; R^2 = OH. **3.** R = CH_3CO

Porphyrins

Many bacteria in the genus *Arthrobacter* produce red pigment porphyrins. A compound belonging to the family of red extracellular pigments porphyrin was isolated in *A. globiformis, A. photogonimos* and *A. aurescens* and identified as coproporphyrin III, $C_{36}H_{38}N_4O_8$ (Fig. 5). Another form of porphyrin was also described from pigment excreted by *A. hyalinus*. This pigment was identified as uroporphyrin III, $C_{40}H_{38}N_4O_{16}$ (Fig. 6).

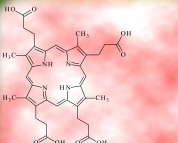


Fig. 5. Chemical structure of coproporphyrin III

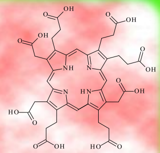


Fig. 6. Chemical structure of uroporphyrin III

Carotenoids

Red-carotenoids accumulation in *Arthrobacter agilis*, a psychrotrophic bacterium isolated from Antarctic sea ice, has been investigated. The pigments were identified as a series of geometrical isomers of the C_{50} carotenoid bacterioruberin (Fig.7). Another *Arthrobacter*, *Arthrobacter roseus* sp. nov., has been also reported to produce red-carotenoids.

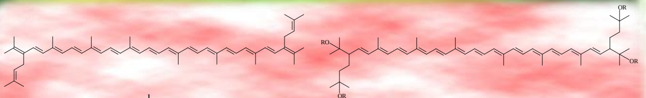


Fig. 7. Chemical structures of carotenoids produced by *Arthrobacter agilis*. **1.** tetra-anhydrobacterioruberin. **2.** Bacterioruberin: R=H; a series of glycosylated derivatives: R=H, hexose or dihexose

Indochrome

Apart from indigoidine, other chromophores of the water-soluble pigments produced by *A. atrocyaneus* and *A. polychromogenes* were identified as indochromes with chemical formula $C_{20}H_{23}N_3O_{12}$ (Fig. 4). These pigments were released into the culture liquid only by indigoidine-producing bacteria.

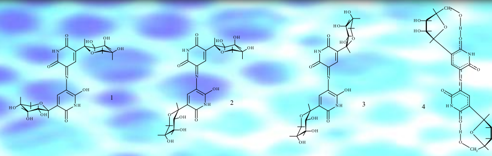


Fig. 4. Chemical structures of indochrome produced by *Arthrobacter polychromogenes*

CONCLUSION

Pigments produced by microorganisms gain interest from the scientific community not only as a taxonomic tool to identify classify the microorganisms but also for a commercial purpose. The utilization of natural pigments in manufacturing has been increasing since the nineties due to the consumer awareness of the toxicity problems linked to synthetic pigments. Microorganisms seem to be a reasonable choice for colorant production due to biotechnological advantages e.g. production regardless of season and geographical conditions; controllable and predictable yield. The genus *Arthrobacter* is one among diverse microorganisms which has been found to produce pigments with several hues. Furthermore, these bacteria have been commonly found in various environments. By these advantageous points, the study of the bacteria belonging to the genus *Arthrobacter* might lead to the discovery a novel source of natural colorants.

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PIGMENTS PRODUCED BY THE BACTERIA BELONGING TO THE GENUS *ARTHROBACTER*

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Abstract

Since several decades, pigments have been used as a taxonomic tool for the identification and classification of bacteria. Nowadays, pigment producing microorganisms have been also widely interested in scientific disciplines because of their biotechnological potential. With the growing interest in microbial pigments because of factors such as production regardless of season and geographical conditions, novel microorganisms which their pigments can be extracted are being evaluated. In the nature, a numerous number of microorganisms e.g. yeast, fungi, algae and bacteria produce pigments. The genus *Arthrobacter* is one among diverse microorganisms which has been found to produce pigments. Most of bacteria in this genus produce a range of pigments. Several previous studies show that pigments produced by bacteria belonging to the genus *Arthrobacte*r have various hues depending on the chromophore which is present, e.g. yellow by carotenoid and riboflavin, green and blue by indigoidine and indochrome, and red by porphyrins and carotenoids. Since long time numerous strains in this genus have been reported that their colonies are colored; however, the purification and characterization of their pigments were not frequently conducted until well know chemical structures and role in these strains. Consequently, a study of pigments produced by the genus *Arthrobacter* may be worthy to play attention for discovering a novel source of natural colourants.

References

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PROGRAM

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June 18-21, 2013
Novara, Italy

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SCIENTIFIC PROGRAM

18 JUNE

16.30 - 17.00	**Opening ceremony and welcome**

SESSION 1 CHEMISTRY AND BIOCHEMISTRY

17.00 - 17.40	**Plenary lecture Prof. G. BRITTON (University of Liverpool, U.K.)** **"NATURAL CAROTENOIDS: A STUDY IN OILS AND WATER COLOURS"**
17.40 - 18.00	**CAROTENOID ESTER PROFILES IN *SOLANUM TUBEROSUM* AND *SOLANUM PHUREJA* CULTIVARS** Burmeister A., Bondiek S., Jerz G., Fleischmann P. Institute of Food Chemistry, TU Braunschweig, Braunschweig, Germany
18.00 - 18.20	**INTRAMOLECULAR AND INTERMOLECULAR FACTORS AFFECTING THE DEGRADATION KINETICS OF XANTHOPHYLL ESTERS** Jarén-Galán M., Hornero-Méndez D., Pérez-Gálvez A. Food Biotechnology Department, Instituto de la Grasa (CSIC), Sevilla, Spain.
18.20 - 18.40	**ANALYTICAL AND TECHNOLOGICAL ASPECT OF CAROTENOIDS FROM RED-BELL PEPPER** Daood H.G., Palotas G., Palotas G., Pek Z.; Helyes L. Szent Istvan University & Univer Products PSI

19 JUNE

SESSION 1 CHEMISTRY AND BIOCHEMISTRY

9.00 - 9.40	**Plenary lecture Prof. Ø.M. ANDERSEN (University of Bergen, Norway)** **"DIFFERENCES IN ANTHOCYANIN CONTENT OF FOOD AND NATURAL SOURCES CORRELATED WITH DIFFERENCES IN ANTHOCYANIN CHEMISTRY AND PROPERTIES"**
9.40 - 10.00	**ANTHOCYANIN-SYNTHESIZING TOMATO GENOTYPE 'SUN BLACK™' AS PRINCIPAL INGREDIENT FOR A NEW FUNCTIONAL TOMATO SAUCE** Blando F.[1], Albano C.[1], Gerardi C.[1], Mita G.[1], Mazzucato A.[2] [1] Institute of Sciences of Food Production, CNR, Lecce, Italy; [2] Department of Sciences and Technologies for Agriculture, Forestry, Nature and Energy, Tuscia University, Viterbo, Italy
10.00 - 10.20	**STUDIES ON COUPLING REACTIONS OF PROANTHOCYANIDINS AND MALVIDIN-3-O-GLUCOSIDE IN A WINE-LIKE MODEL SOLUTION SYSTEM** Nickolaus P., Weber F., Durner D. Competence Center for Viticulture & Enology, Neustadt an der Weinstraße, Germany.
10.20 - 10.40	**POST-HARVEST MODIFICATIONS ENHANCE THE ZEAXANTHIN CONTENT IN VEGETABLES** Esteban R.[1], Fleta E.[1], Buezo J.[1], Miguez F.[1], Becerril J.M.[1], García-Plazaola J.I.[1] [1] Department of Plant Biology and Ecology, University of Basque Country, UPV/EHU, Bilbao, Spain
10.40 - 11.00	**Coffee break**
11.00 - 12.00	**TIME FOR POSTER SESSION**
12.00 - 12.20	**DESCRIPTION OF A NEW CHLOROPHYLL CATABOLITE IN RIPENED FRUITS OF QUINCE (*Cydonia Oblonga*, Mill.)** Roca M., Ríos J.J., Pérez-Gálvez A. Food Biotechnology Department, Instituto de la Grasa (CSIC), Sevilla, Spain.
12.20 - 12.40	**RELATIONSHIPS AMONG FLAG LEAF CHLOROPHYLL CONTENT, AGRONOMICAL TRAITS, AND SOME PHYSIOLOGICAL TRAITS OF WINTER BREAD WHEAT GENOTYPES** Bahar B., Sirat A., Kilic R., Aydin I. (Siran Vocational School, Gumushane University, Gumushane, Turkey)
12.40 - 13.00	**OXIDATION ROUTES FOR BETACYANINS** Wybraniec S.[1], Szot D.[1], Nemzer B.[2], Pietrzkowski Z.[3] [1]Department of Analytical Chemistry, Cracow University of Technology, Cracow, Poland; [2]Chemistry Research, FutureCeuticals Inc., Momence, IL, USA; [3]Applied BioClinical Inc., Irvine, CA, USA.

19 JUNE

SESSION 2 (part 1) TECHNOLOGY, BIOTECHNOLOGY, AND PROCESSING

14.00 - 14.40	**Plenary lecture prof. Vural GÖKMEN (Hacettepe University, Ankara, Turkey)** **"ARTIFICIAL INTELLIGENCE: IMPROVING THE COLOR MEASUREMENT"**
14.40 - 15.00	**INFLUENCE OF SOME OAK WOOD COMPONENTS ON STABILITY OF MALVIDIN-3-GLUCOSIDE AND CHROMATIC CHARACTERISTICS IN MODEL WINE SOLUTIONS** Correia A.C., Jordão A.M. Agrarian Higher School, Polytechnic Institute of Viseu (CI&DETS), Viseu, Portugal.
15.00 - 15.20	**STABILIZATION OF ANTHOCYANIN–METAL CHELATES WITH HYDROCOLLOIDS FOR THEIR APPLICATION AS BLUE FOOD COLORANTS** Buchweitz M., Kammerer D. R., Carle R. Institute of Food Science and Biotechnology, Chair Plant Foodstuff Technology, Hohenheim University, Stuttgart, Germany.
15.20 - 15.40	**STABILISATION OF BEETROOT DERIVED BETANIN THROUGH INTERACTION WITH AN EXTRACT FROM BARBADOS CHERRY** Kendrick A. Diana Food Division, Rennes, France.
15.40 - 16.20	**Plenary LECTURE Prof. G. CRAVOTTO (University of Turin, Italy)** **"MICROWAVE AND ULTRASOUND ASSISTED FOOD PIGMENTS EXTRACTION: HIGHLY EFFICIENT REACTORS FOR GREEN, SUSTAINABLE PROCESSES"**

20 JUNE

SESSION 3 PIGMENTS FROM MICROALGAE

9.00 - 9.40	**Plenary lecture Prof. Eriksen N.T. (University of Aalborg, Denmark)** **PIGMENTS FROM MICROALGAE: A NEW PERSPECTIVE WITH EMPHASIS ON PHYCOCYANIN**
9.40 - 10.00	**Invited lecture** **ALGAL CAROTENOIDS AS NOVEL PIGMENTS IN NUTRITION** Christaki E. Laboratory of Nutrition, Faculty of Veterinary Medicine, Aristotle University of Thessaloniki, Thessaloniki, Greece.
10.00 - 10.20	**FUNCTIONAL FOOD DEVELOPMENT USING AQUEOUS EXTRACT OF ARTROSPIRA (SPIRULINA) MAXIMA RICH IN PHYCOBILIPROTEINS** Langellotti A.L., Buono S., Vargas I., Martello A., Fogliano V. CRIAcq Research Centre, University of Naples “Federico II”, Portici, Italy
10.20 - 10.40	**Coffee break**
10.40 - 11.40	**TIME FOR POSTER SESSION**

SESSION 2 (part 2) TECHNOLOGY, BIOTECHNOLOGY, AND PROCESSING

11.40 - 12.00	**NATURAL HYDROXYANTHRAQUINOID PIGMENTS: CURRENT SITUATION AND FUTURE OPPORTUNITIES IN FOOD** Caro Y., Fouillaud M., Laurent P., Dufossé L. Laboratoire de Chimie des Substances Naturelles et des Sciences des Aliments, Université de la Réunion, Sainte-Clotilde, Ile de la Réunion, France
12.00 - 12.20	**DEGRADATION OF ANTHOCYANINS IN PROCESSED STRAWBERRY FRUIT** Kermasha S., Borgomano S. Department of Food Science and Agricultural Chemistry, McGill University, Ste-Anne de Bellevue, Canada
12.20 - 13.00	**“Short communications“ from selected posters**

21 JUNE

SESSION 4 HEALTH AND NUTRITION

9.00 - 9.40

Plenary lecture Dr. Schweiggert (University of Hohenheim, Germany)

ENHANCED BIOAVAILABILITY OF CAROTENOIDS: THE INFLUENCE OF CHROMOPLAST MORPHOLOGY DIETARY LIPID, AND THERMAL PROCESSING

Schweiggert R.M.[1,2], Kopec R.E.[2,6], Cooperstone J.L.[2], Villalobos-Gutierrez M.G.[3], Högel J.[4], Young G.S.[5], Francis D.M.[7], Quesada S.[8], Esquivel P.[3], Schwartz S.J.[2], Carle R.[1]

9.40 - 10.00

BIOACCESSIBILITY AND CHANGES IN THE CAROTENOID PROFILE FROM MURICI FRUIT AFTER *IN VITRO* GASTROINTESTINAL DIGESTION

Mariutti L., Rodrigues E., Mandelli F., Mercadante A.
Department of Food Science, University of Campinas, Campinas, Brazil.

10.00 - 10.20

A MINI REVIEW ON THE COLOURLESS CAROTENOIDS PHYTOENE AND PHYTOFLUENE. ARE THEY INVISIBLE BIOACTIVE COMPOUNDS?

Meléndez-Martínez A. J.[1,2], Mapelli Brahm P.[2], Stinco C.M.[2] and Wang X-D.[1,3]
[1]J. Mayer USDA Human Nutrition Research Center on Aging at Tufts University, Boston, MA; [2] Food Colour & Quality Laboratory, Department of Nutrition and Food Science, Universidad de Sevilla, Sevilla, Spain; [3] Department of Nutritional Science, Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy, Tufts University, Boston, MA.

10.20 - 10.40

DISSECTING THE PHARMACOPHORE OF CURCUMIN: TWO CASE STUDIES

Minassi A., Appendino G.
Department of Pharmaceutical Sciences, University of Piemonte Orientale "A. Avogadro", Novara, Italy.

10.40 - 11.00 **Coffee break**

11.00 - 12.30 **ROUND TABLE:** New natural pigments from foods: technical applicability and regulatory affairs

12.30 - 13.00 **Closure ceremony and advertisement of next PIF**

Poster Session

P 01: Synthesis of water-soluble carotenoids via click-reaction
Agócs A., Háda M., Nagy V., Deli J.

P 02: Thermal and light stability of β-cryptoxanthin esters
Bunea A., Andrei S., Rugină D., Pintea A.

P 03: Effect of esterification on thermal stability and antioxidant activity of zeaxanthin
Pintea A., Bunea A., Socaciu C.

P 04: Measurement of enzymatic hydrolysis of lutein esters from dairy products during *in vitro* digestion
Xavier A.A.O., Garrido-Fernández J., Mercadante A.Z., Pérez-Gálvez A..

P 05: Oil bodies as a potential microencapsulation carrier for astaxanthin stabilization and safe delivery
Acevedo F., Rubilar M., Villarroel M., Navarrete P., Jofré I., Romero F., Acevedo V., Shene C..

P 06: Microencapsulation of astaxanthin oleoresin from *Phaffia rhodozyma*
Villalobos-Castillejos F., Yáñez-Fernández J., Barragán-Huerta B.E.

P 07: Effect of genotype and growing conditions on lutein and β-carotene content of green leafy *Brassica* species
Arrigoni E., Reif C., Berger F., Baumgartner D., Nyström L.

P 08: Effect of processing on content of vital carotenoids in new vegetable puree
Palotás Gábor, Palotás Gábriella, Daood H., Pék Z., Helyes L.

P 09: Effect of addition of sodium erythorbate and urucum on the lipid oxidation in pork meat
Figueiredo B., Bragagnolo N.

P 10: Identification of *Cionosicyos macranthus* carotenoids
Murillo E., Watts M., Reyna G.

P 11: Bioactive compounds in supercritical CO_2-extracted pumpkin oil
Durante M., Lenucci M.S., D'Amico L., Dalessandro G., Mita G.

P 12: Evaluation of carotenoids and capsaicinoids content in powder of chilli peppers during one year of shelf-life
Giuffrida D., Cavazza A., Dugo P., Torre G., Corradini C., Bignardi C., Dugo G.mo

P 13: Carotenoids in red fleshed sweet oranges
Merussi G.D., Latado R.R., Rossi E.A., Sylos C.M.

P 14: Colour changes in heat-treated orange juice during ambient storage
Wibowo S., Vervoort L., Lemmens L., Hendrickx M., Van Loey A.

P 15: Carotenoid deposition and profiles in peach palm (*Bactris gasipaes* Kunth) fruits, and their implication on its nutritional potential
Hempel J., Esquivel P., Carle R., Schweiggert R.M.

P 16: Deposition of lycopene, β-carotene, and β-cryptoxanthin in different chromoplast substructures in papaya fruits
Schweiggert R.M., Steingass C.B., Heller A., Esquivel P., Carle R.

P 17: Evaluation of quality parameters and carotenoid content of three cultivars of mango (Mangifera indica L.) from Réunion island
Rosalie R., Chillet M., Joas J., Lechaudel M., Payet B., Vulcain E., Dufossé L.

P 18: Genuine profiles and bioaccessibilities of carotenoids from red- and yellow-fleshed Mamey sapote (*Pouteria sapota*) fruits
Chacón-Ordóñez T., Jiménez V.M., Esquivel P., Carle R., Schweiggert R.M.

P 19: Trasgenic tomatoes and their carotenoid and flavour profiles
Höfelmeier H., Burmeister A., Schwab W., Fleischmann P.

P 20: Study of the time-course *cis/trans* isomerisation of lycopene, phytoene and phytofluene from tomato
Meléndez-Martinez A.J., Paulino M., Stinco C.M., Wang X.-D.

P 21: Carotenoid composition of three Hungarian algae species
Deli J., Vasas G., Parizsa P., Hajdú G., Szabó I., Lambert N.

P 22: HPLC method validation for the determination of fucoxanthin
Travaglia F., Bordiga M., Locatelli M., Coïsson J.D., Arlorio M.

P 23: Carotenoids stabilisation for use in beverages: two different approaches
Mesnier X., Boukobza F., Bily A., Roller M.

P 24: Effect of heat processing on the profile of pigments and antioxidant capacity of Jalapeño peppers at intermediate ripening stages
Cervantes-Paz B., Ornelas-Paz J. de J., Yahia E.M.

P 25: Micellarization and digestive stability of pigments from Jalapeño peppers at intermediate ripening stages
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