Magnetically responsive waste biomaterials for biotechnology and environmental technology applications

Ivo Safarik and Jitka Prochazkova

Department of Nanobiotechnology,

Biology Centre, ISBB, CAS, Ceske Budejovice, Czech Republic

ivosaf@yahoo.com

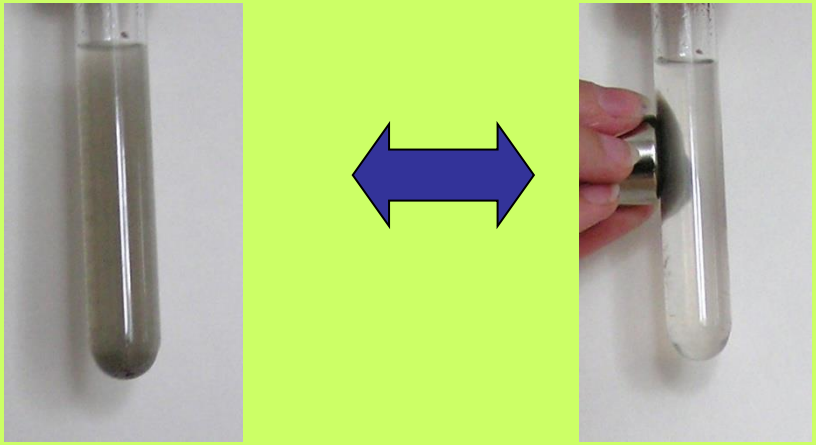
Why magnetic materials are so important in bio- and environmental applications?

They are smart materials!!!!

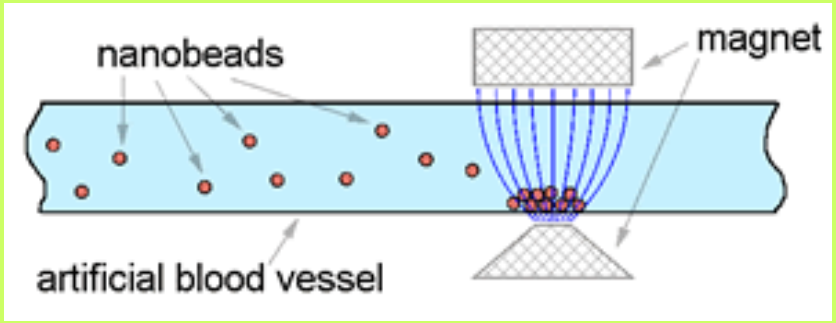
The following typical properties of magnetic materials form the basis of their applications in biosciences, biotechnology, medicine and environmental technology

Important properties

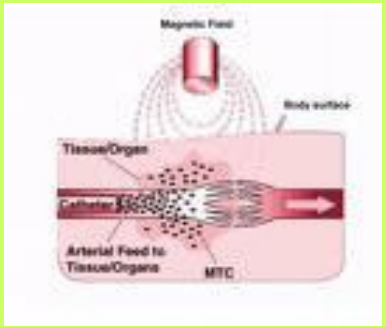
- Selective separation (removal) of magnetic particles from the system

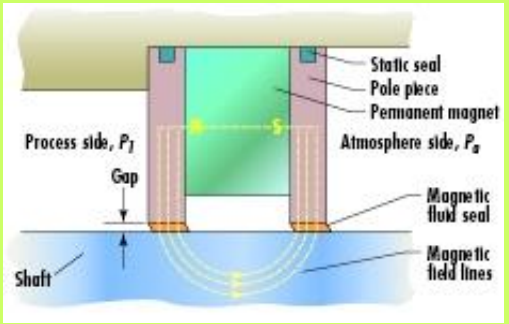


- Targeting (navigation) of magnetic particles to desired area using magnetic field



- “Keeping” magnetic particles in appropriate area using magnetic field

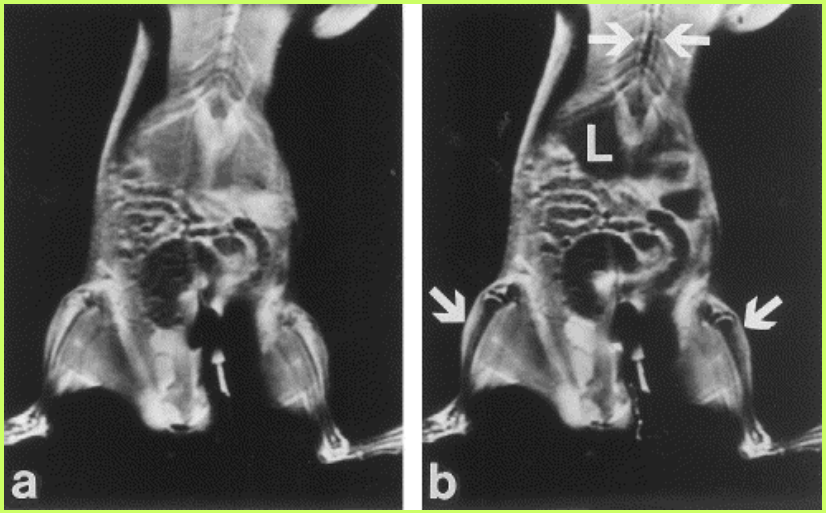




Important properties

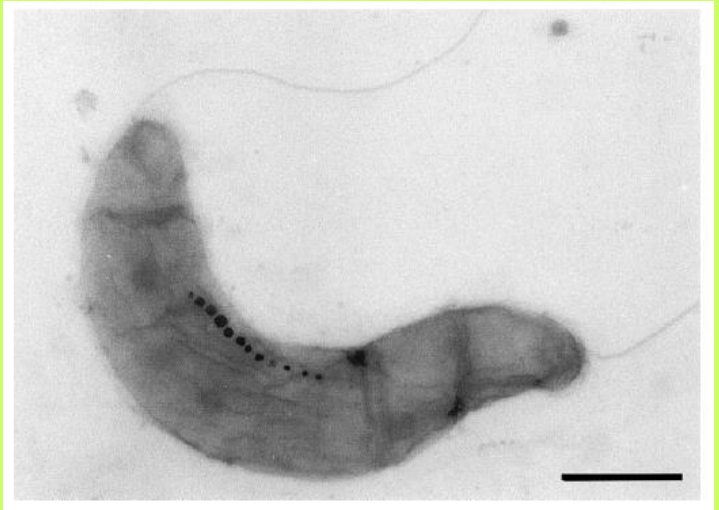
- Heat formation in alternated magnetic field

- Increasing of contrast during MRI

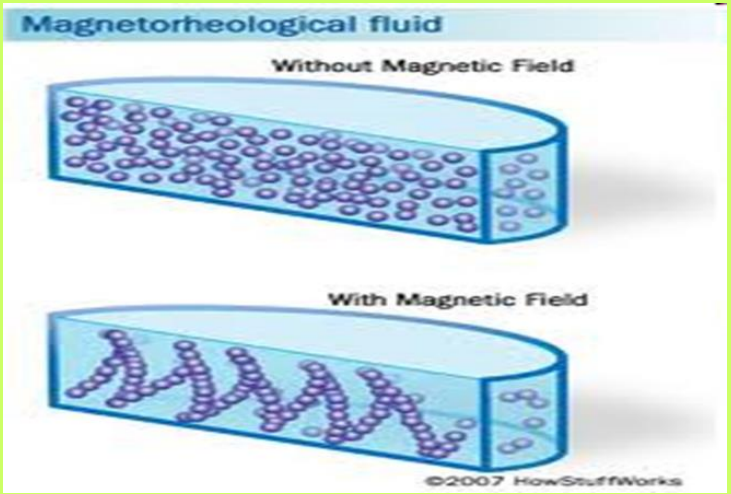


Important properties

- Navigation in magnetic field

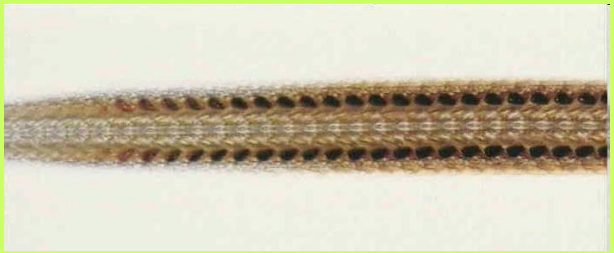


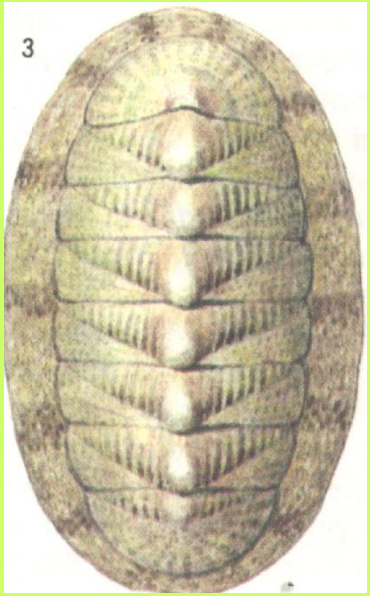
- Increase of viskosity (magnetorheological fluids)



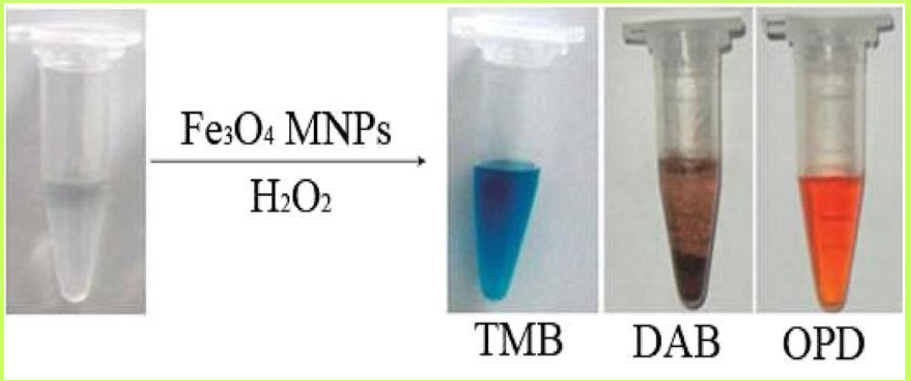
Further important properties

- Hardening of biological structures (chiton teeth)





- Peroxidase-like activity



Applications of magnetically responsive nano- and micromaterials

- From molecular biology to environmental technologies
- Manipulation of microliters as well as million of liters
- Manipulation in suspension systems
- Both separation and non-separation techniques are important

Magnetically responsive biomaterials

Magnetic modification leads to the formation of smart materials!!!!

Diamagnetic biomaterials for magnetic modification

Food wastes belong to the broader group of biomaterials

- Biomaterials - organic
  - inorganic (egg shells, oyster shells…)
- Character - particulate
  - high aspect ratio

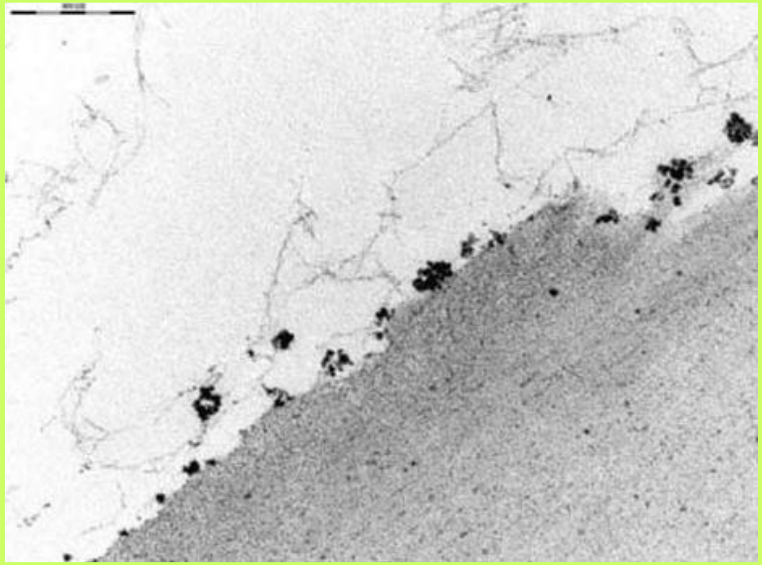
Magnetic materials used for the preparation of magnetically responsive biomaterials

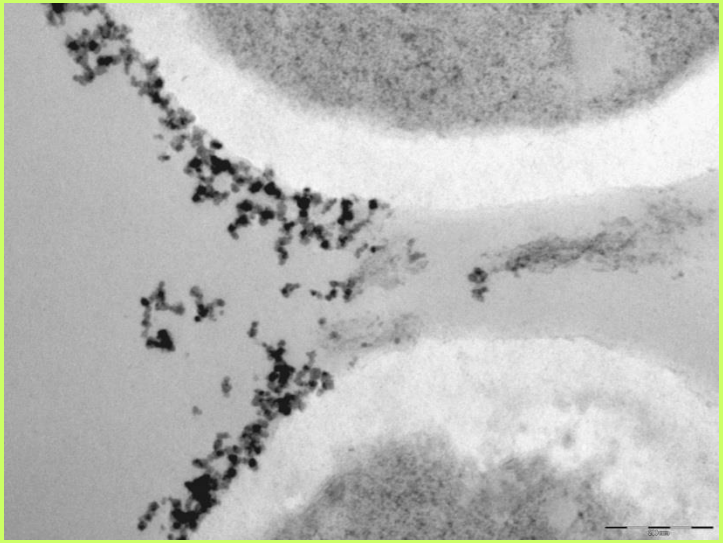
- Magnetic iron oxides
  - magnetite (Fe_3O_4)
  - maghemite (Fe_2O_3)
  - **mixed iron oxides**

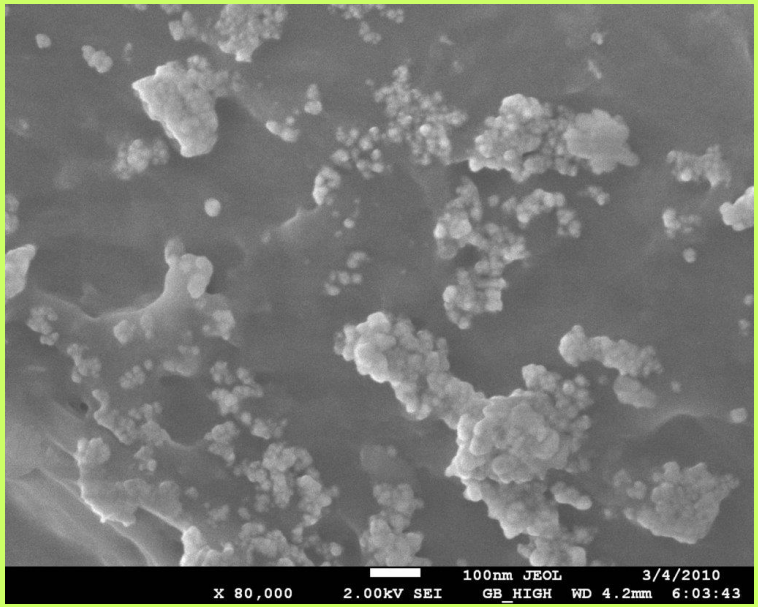
- Ferrites
  - MeO. Fe_2O_3 , Me = Ni, Co, Mg, Zn, Mn ...

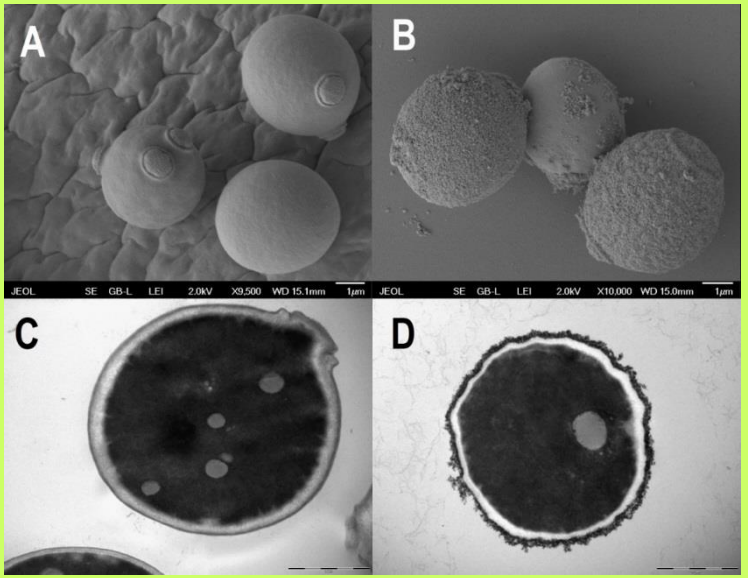
Magnetic iron oxides are biocompatible!!

Postmagetization with ferrofluids

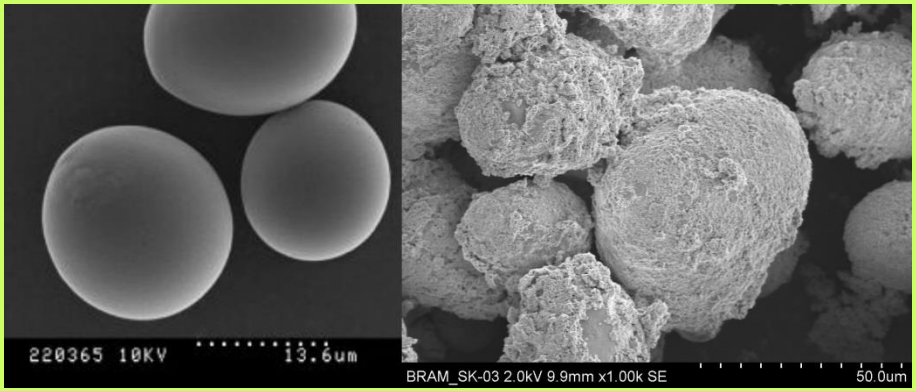


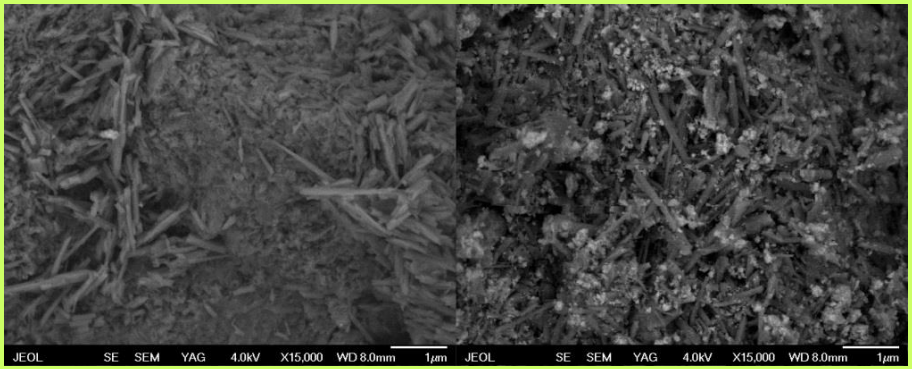






Mechanochemical treatment





- Mechanochemical conversion of ferrous and ferric ions at the presence of alkaline hydroxide into magnetic iron oxide nanoparticles.
- The presence of powdered nonmagnetic materials during the process led to the efficient deposition of magnetic nanoparticles on the surface of the treated materials

Safarik,I., Horska,K., Pospiskova,K., Filip,J., Safarikova,M.: Mechanochemical synthesis of magnetically responsive materials from non-magnetic precursors. Materials Letters 126 (2014) 202-206

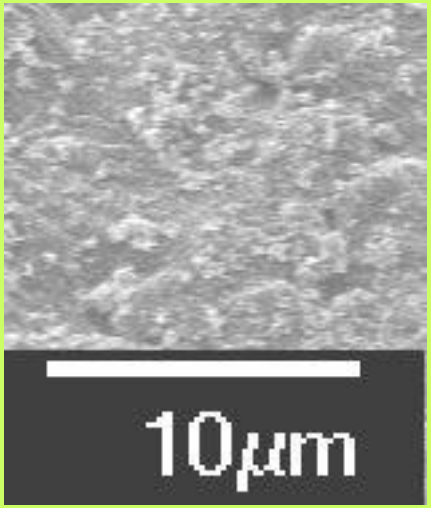
Direct microwave assisted procedure

$FeSO_4.7H_2O$

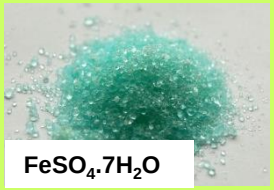
microwave oven

KOH

Safarik,I., Horska,K., Pospiskova,K., Maderova,Z., Safarikova,M.: Microwave assisted synthesis of magnetically responsive composite materials. IEEE Trans. Magn. 49 (1) (2013) 213-218



Indirect microwave assisted procedure



$FeSO_4.7H_2O$

KOH

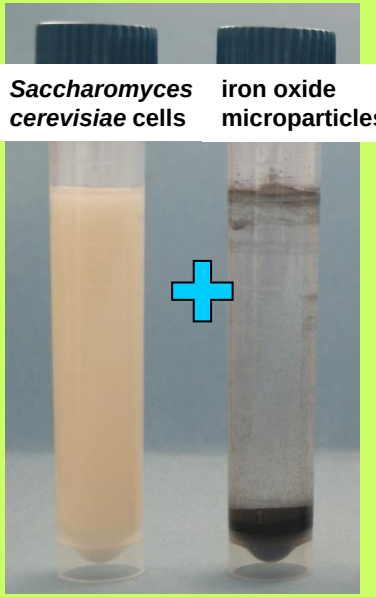
microwave oven

Pospiskova,K., Prochazkova,G., Safarik,I.: One-step magnetic modification of yeasts cells by microwave synthesized iron oxides microparticles. Lett. Appl. Microbiol. 56 (2013) 456-461

microwave assisted synthesis of magnetic **iron oxide microparticles**

$$Fe^{2+} + OH^- \rightarrow Fe(OH)_2$$

$$3Fe(OH)_2 + 1/2O_2 \xrightarrow{\text{microwave}} Fe_3O_4 + 3H_2O$$



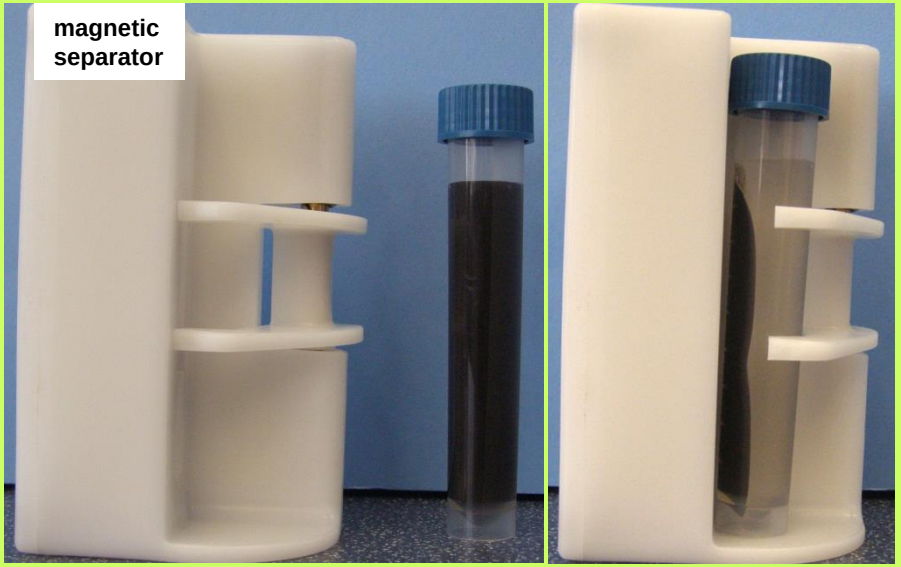
***Saccharomyces cerevisiae* cells** **iron oxide microparticles**

Yeast cells

Magnetic material

magnetic modification procedure

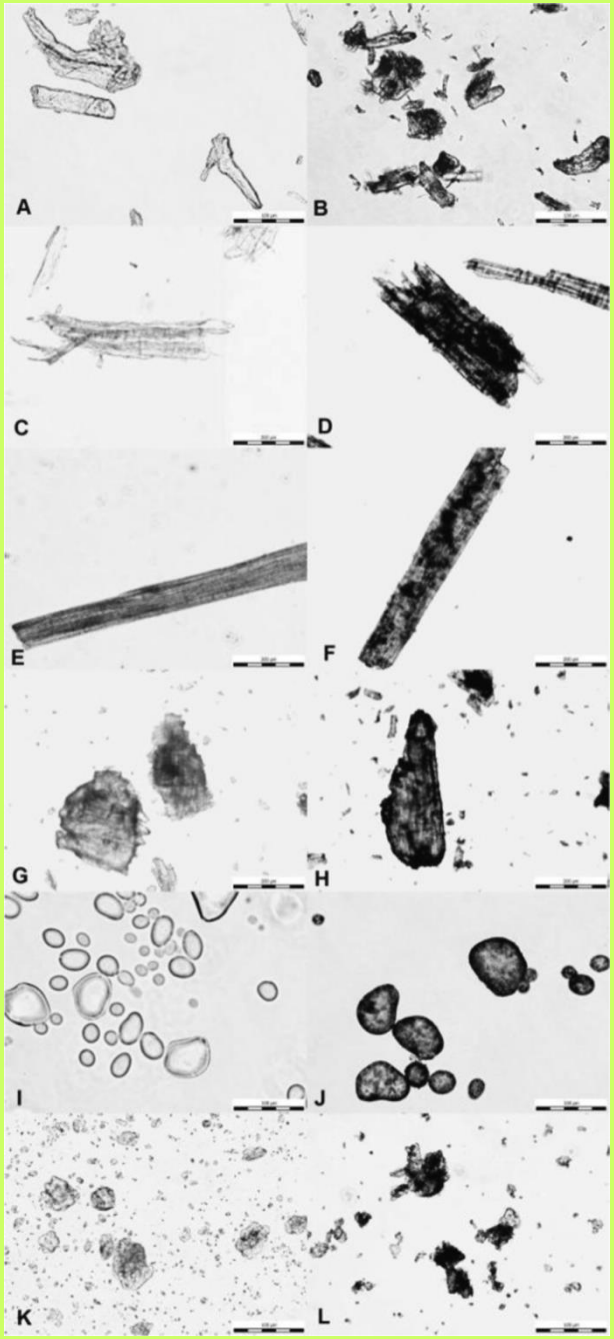
magnetically modified cells

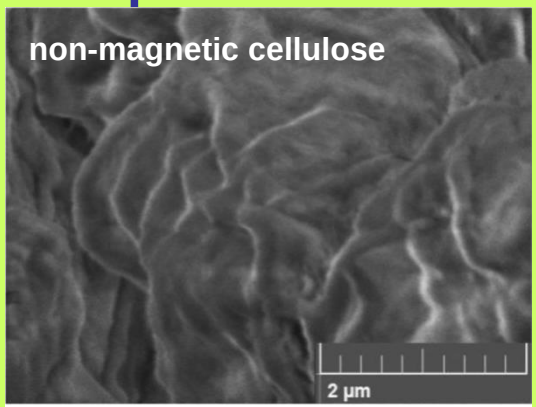


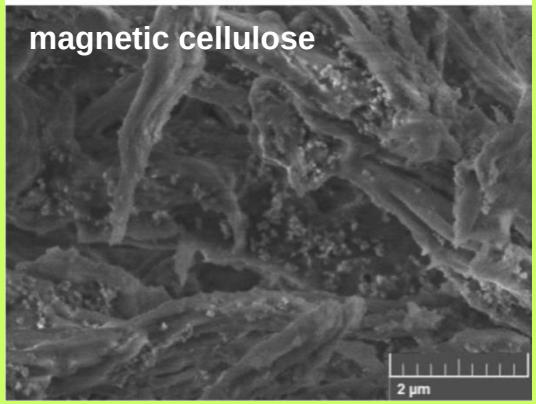
magnetic separator

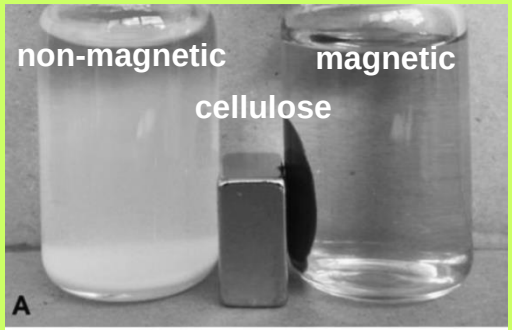
Magnetically responsive microbial cells

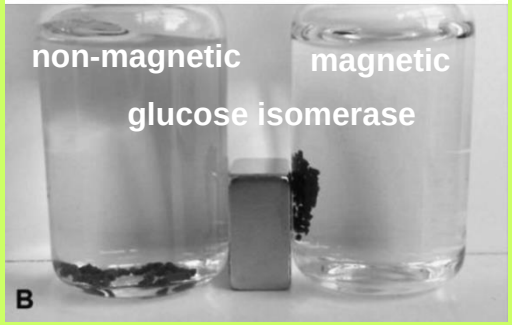
Subzero temperature modification











magnetic separation

non-magnetic (A) and magnetic (B) cellulose
non-magnetic (C) and magnetic (D) spruce sawdust
non-magnetic (E) and magnetic (F) marinegrass *Posidonia oceanica*
non-magnetic (G) and magnetic (H) powdered peanuthusks
non-magnetic (I)and magnetic (J) starch
Non-magnetic (K) and magnetic (L) montmorillonite K10

Pospiskova,K., Safarik,I.: Low-temperature magnetic modification of sensitive biological materials. Mater. Lett. 142 (2015) 184-188

Pospiskova,K., Safarik,I.: Magnetically responsive enzyme powders. J. Magn. Magn. Mater. 380 (2015) 197-200

Magnetically modified biomaterials in our lab

Typical food, agricultural and forest wastes and related biomaterials

- Spent grain, spent coffee, spent tee, peanut husks, straw, sawdust
- Chitin, chitosan, alginate, bacterial cellulose, starch, wheat bran, moss, erythrocytes, egg white

Microbial and microalgae cells

- *S. cerevisiae*, *S. uvarum*, *Kluyveromyces fragilis*, *Leptothrix* sp., *Chlorella*

Macroalgae

- *Sargassum, Ulva, Cymopolia*

Seagrass

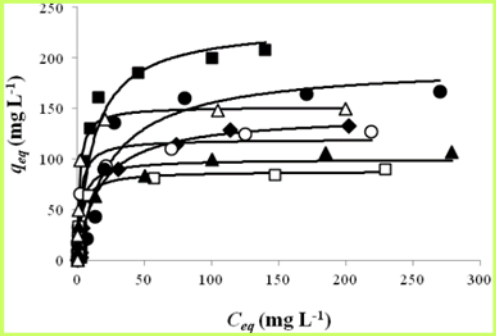
- *Posidonia oceanica*

Biochars !!!

Removal of important pollutants

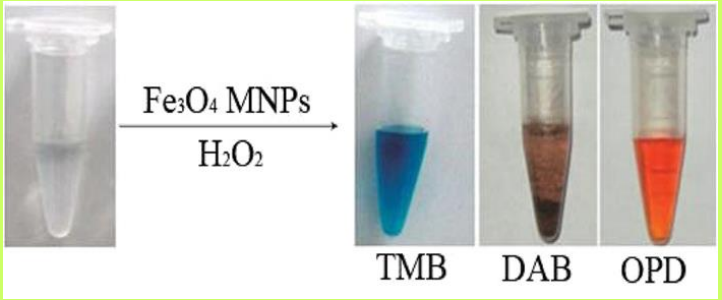
- **Organic dyes**

- Many different types of biomaterials



- **Bisphenol A**

- Spruce chip biochar



- **Heavy metal ions**

- Microbial cells

- Spent coffee grains

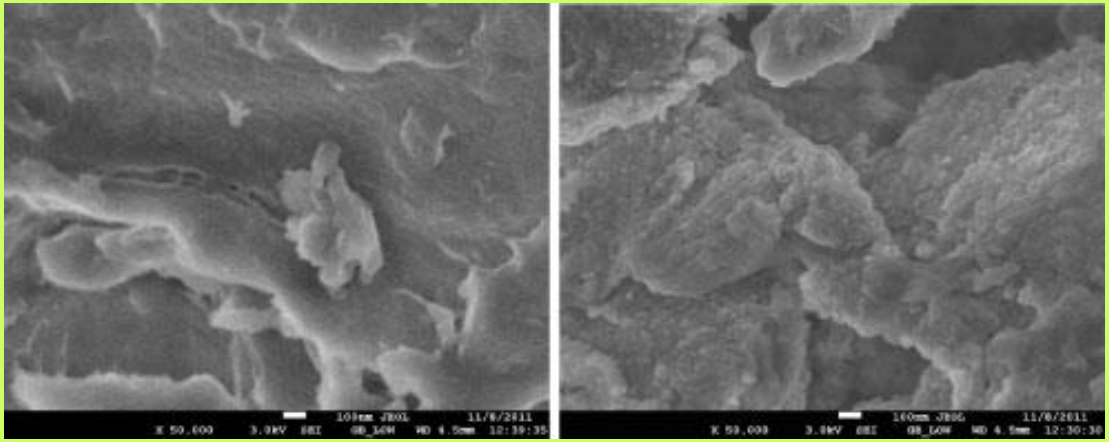
- **Radionuclides**

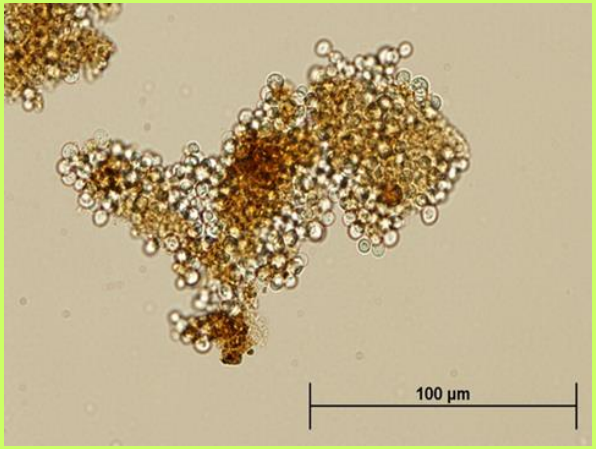
- Strontium (*Kluyveromyces fragilis*)
- Uranium (wheat bran)

Isolation of biologically active compounds

- Potato lectin (chitosan)
- Chitinase III in *Euphorbia characias* latex (chitin)
- Lysozyme (chitosan)
- Proteases (erythrocytes)
- Amylases (alginate)
- Cyclodextrin glucanotransferase (porous corn starch)

Immobilization of enzymes and cell on magnetically modified biomaterials



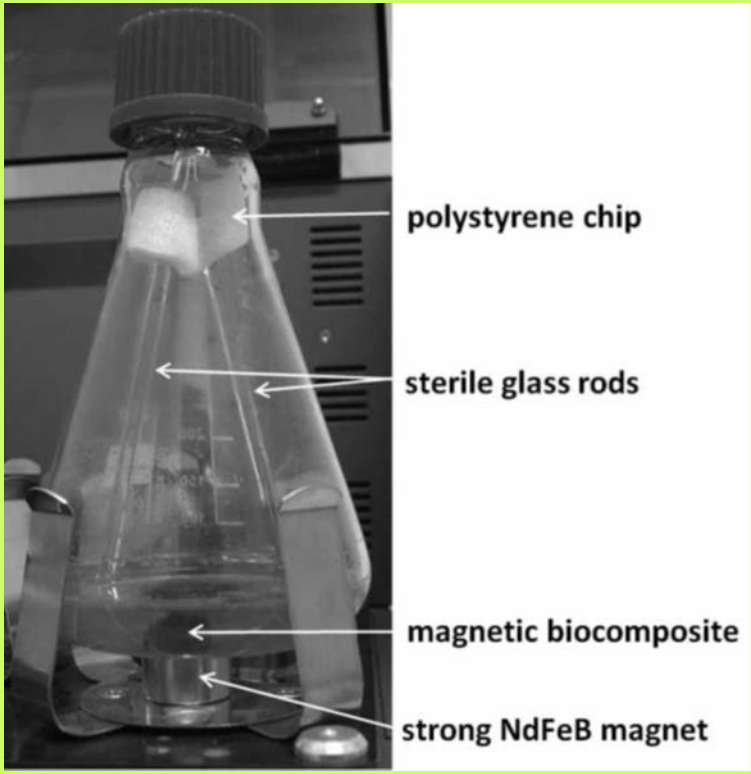


Pospiskova,K., Safarik,I.: Magnetically modified spent grain as a low-cost, biocompatible and smart carrier for enzyme immobilization. J. Sci. Food Agric. 93 (2013) 1598-1602

Safarik,I., Pospiskova,K., Maderova,Z., Baldikova,E., Horska,K., Safarikova,M.: Microwave - synthesized magnetic chitosan microparticles for the immobilization of yeast cells. Yeast 32 (2015) 239-243

Decrease of biofilm formation

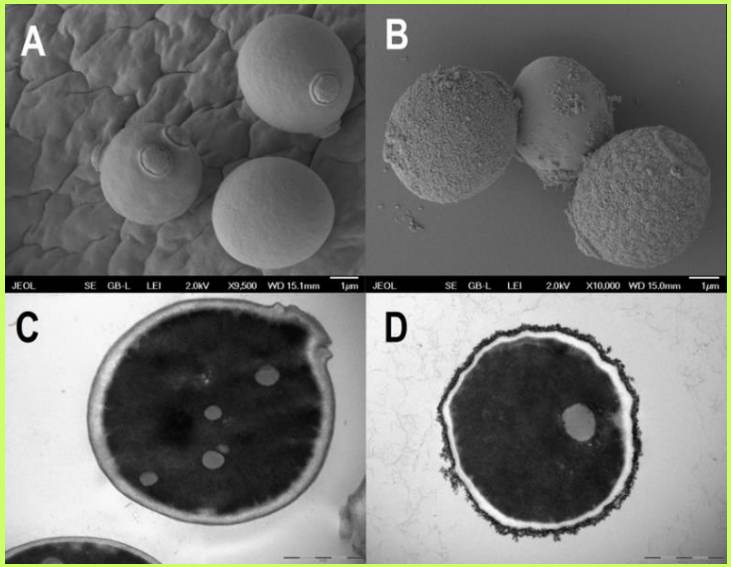
Efficient removal of signal molecules using magnetically modified spent grain → decrease of biofilm formation



Maderova,Z., Horska,K., Kim,S.-R., Lee,C.-H., Pospiskova,K., Safarikova, M., Safarik,I.: Decrease of *Pseudomonas aeruginosa* biofilm formation by food waste materials. Water Sci. Technol. 73 (9) (2016) 2143-2149

Catalytical applications

- Hydrogen peroxide removal (*S. cerevisiae*)
- Saccharose hydrolysis (*S. cerevisiae*)



Safarik, I., Sabatkova, Z., Safarikova, M.: Hydrogen peroxide removal with magnetically responsive Saccharomyces cerevisiae cells. J. Agric. Food Chem. 56 (2008) 7925-7928

Safarikova,M., Maderova,Z., Safarik,I.: Ferrofluid modified Saccharomyces cerevisiae cells for biocatalysis. Food Res. Int. 42 (2009) 521-524

Biochars and their magnetic derivatives exhibit peroxidase-like activity

Biotechnology

- Magnetically responsive materials for

  - circular economy

Safarik, I., Baldikova, E., Prochazkova, J., Safarikova, M., Pospiskova, K.: Magnetically modified agricultural and food waste: Preparation and application. J. Agric. Food Chem. 66 (2018) 2538-2552

  - biorefinery concepts

Safarik,I., Pospiskova,K., Baldikova,E., Safarikova,M.: Development of advanced biorefinery concepts using magnetically responsive materials. Biochem. Eng. J. 116 (2016) 17-26

Review papers and book chapters

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Review

Cite This: J. Agric. Food Chem. 2018, 66, 2538−2552

pubs.acs.org/JAFC

Magnetically Modified Agricultural and Food Waste: Preparation and Application

Ivo Safarik,*[†‡] Eva Baldikova,[†] Jitka Prochazkova,[†] Mirka Safarikova,[†] and Kristyna Pospiskova*[‡]

[†]Department of Nanobiotechnology, Biology Centre, Institute of Soil Biology (ISB), Czech Academy of Sciences (CAS), Na Sadkach 7, 370 05 Ceske Budejovice, Czech Republic

[‡]Regional Centre of Advanced Technologies and Materials, Palacky University, Slechtitelu 27, 783 71 Olomouc, Czech Republic

ABSTRACT: The annual food and agricultural waste production reaches enormous numbers. Therefore, an increasing need to valorize produced wastes arises. Waste materials originating from the food and agricultural industry can be considered as functional materials with interesting properties and broad application potential. Moreover, using an appropriate magnetic modification, smart materials exhibiting a rapid response to an external magnetic field can be obtained. Such materials can be easily and selectively separated from desired environments. Magnetically responsive waste derivatives of biological origins have already been prepared and used as efficient biosorbents for the isolation and removal of both biologically active compounds and organic and inorganic pollutants and radionuclides, as biocompatible carriers for the immobilization of diverse types of (bio)molecules, cells, nano- and microparticles, or (bio)catalysts. Potential bactericidal, algicidal, or anti-biofilm properties of magnetic waste composites have also been tested. Furthermore, low cost and availability of waste biomaterials in larger amounts predetermine their utilization in large-scale processes.

KEYWORDS: *agricultural and food waste, magnetic modification, magnetic biosorbent, magnetic carrier, magnetic (bio)catalyst*

Review papers and book chapters

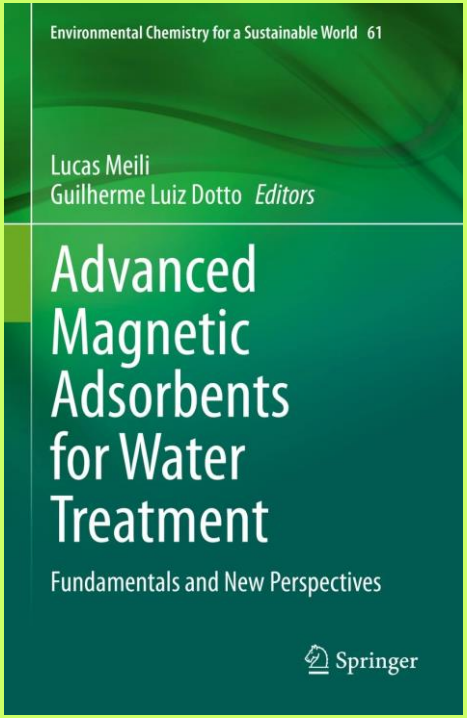
Chapter 8
Magnetically Modified Biological Materials for Dye Removal

Check for updates

Ivo Safarik, Eva Baldikova, Jitka Prochazkova, and Kristyna Pospiskova

Contents

223 237 z 510



Thank you for your attention!

ivosaf@yahoo.com