Ferromagnetic resonance in the ethmoid bones of salmon and silver carp

IOP Conf. Series: Journal of Physics: Conf. Series **903** (2017) 012001 doi:10.1088/1742-6596/903/1/012001

Ferromagnetic resonance in the ethmoid bones of salmon and silver carp

Svitlana Gorobets[1], Oksana Gorobets[1], Volodymyr Golub[1], Marina Gromnadska[2]

[1] Institute of Magnetism of NASU and MESU, Kyiv 03142, Ukraine
[2] Department of General and Experimental Physics, National Technical University of Ukraine "Kyiv Polytechnic Institute", Kyiv 03056, Ukraine

E-mail: pitbm@ukr.net

Abstract. The detection of biogenic magnetic nanoparticles (BMN) with different magnetic properties in biological material was done using magnetic resonance (MR) spectroscopy. MR spectra of biological material of ethmoid bone of salmon (containing ferritin and BMN), bacteria *E. coli* K13 (containing ferritin and without BMN), yeast *S. cerevisiae* (without ferritin or BMN) and ethmoid bone of silver carp (containing ferritin and not investigated for the presence of BMN) were investigated. The analysis of MR spectra shows that *S. cerevisiae* cells produce much lower signal MR than samples of ethmoid bones of salmon and silver carp which is confirming conclusions about the presence of BMN and ferritin in the ethmoid bones of fishes. The narrow MR linewidth indicates that the magnetic particles in the ethmoid bones of salmon and silver carp are in monodisperse state. The presence of a broad line and the absence of a narrow peak in MR spectrum of *E. coli* K13 cells are typical for ferritin.

1. Introduction

In 1962, Lowenstam first discovered biochemically precipitated magnetite as a capping material in the radula (tongue plate) teeth of chitons (marine mollusks of the class Polyplacophora) [1]. In 1975, Blakemore discovered magnetotactic bacteria (MTB) containing chains of BMN. Now magnetotactic bacteria are the most intensively studied biomagnetic systems [1].

Since that BMNs have been detected in a bunch of organisms which are related to all three domains: prokaryotes, archaea and eukaryotes [2]. A number of organisms such as insects, shellfish, fish, birds, mammals can produce biogenic magnetite and/or iron oxide compounds [3]. Biogenic magnetite particles were also found in many human organs [2]. Moreover, some studies have shown the increase of BMN concentrations in the affected area during neurodegenerative diseases and cancer [4]. Thus it is very important to determine the origin of magnetic nanoparticles and develop methods of detection of BMN in living organisms.

2. Experimental procedure

Different biological materials were selected as the objects of the study, namely ethmoid bone of salmon, bacteria *Escherichia coli* K13, yeast *Saccharomyces cerevisiae*, and biological material of ethmoid bone of silver carp.

The choice of biological materials was done based on the analysis of publication data about the presence of BMN and iron-containing proteins, including ferritin (table 1). It is known that *E.coli* has

at least two iron-containing proteins, namely ferritin and bakterioferritin [5] but doesn't contain BMN, while ferritin and BMN presents in ethmoid bone of salmon. *S. cerevisiae* cells do not contain ferritin or BMN. So these cells were used as control samples.

Table 1. Samples of biological material for MR.

The biological material where BMN and ferritin was found (migratory fish)	The biological material containing ferritin and free BMN	The biological material that contains neither ferritin nor BMN	The biological material containing ferritin, but was not investigated for the presence of BMN (non-migratory fish)
Ethmoid bone of salmon [1]	*E.coli* [5]	*S. cerevisiae* [6]	Ethmoid bone of silver carp

Magnetic resonance spectra were recorded for 0.01 g dry biological materials using BrukerBioSpin ELEXSYS E500 spin resonance spectrometer.

3. Results and discussion

MR studies have shown that resonance spectra and intensities of lines for investigated samples of biological materials are quite different. The results of the measurements for the samples of *E. coli* K13, biological material of ethmoid bones of salmon and silver carp, and samples of *S. cerevisiae* are presented in figure 1. The MR spectrum intensity for *S. cerevisiae* cells is much lower than that for other samples. This is in good correlation with literature data: yeast does not contain magnetic nanoparticles. Spectra of biological material of ethmoid bone of salmon and ethmoid bone of silver carp contain a narrow peak around 3.5 kG while there is a quite intense broad peak in *E. coli* K13 spectrum. It should be noted that the intensity of the spectrum of *E. coli* K13 is an order of magnitude lower than that for ethmoid bone of salmon and ethmoid bone of silver carp. The possible explanation of this is the presence of both ferritin and BMN in ethmoid bones of salmon and silver carp.

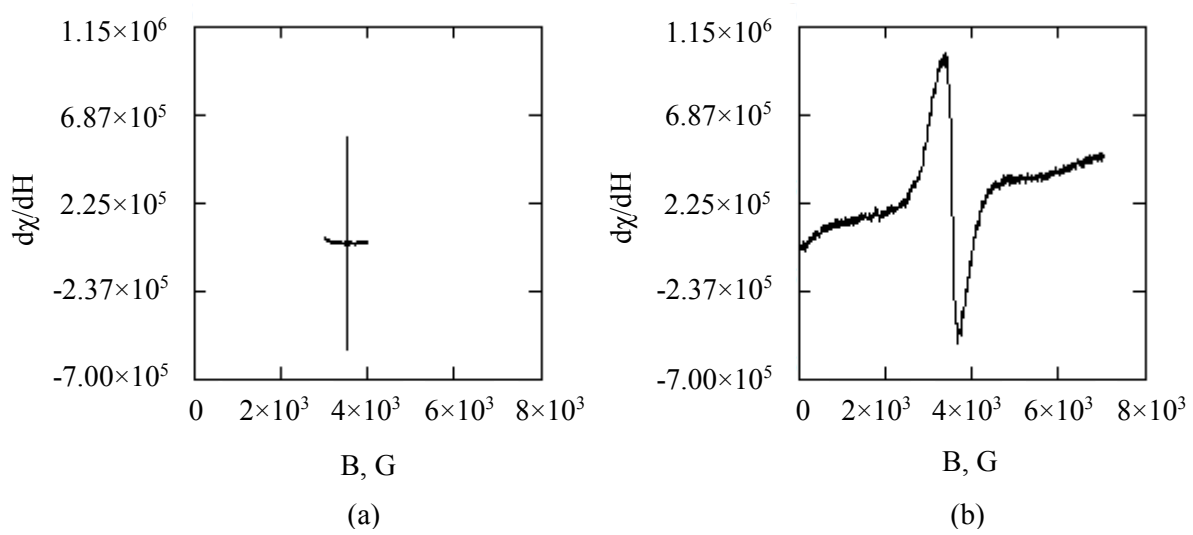

Figure 1. MR spectra for the ethmoid bone of salmon (a), bacteria *E. coli* K13 (b).

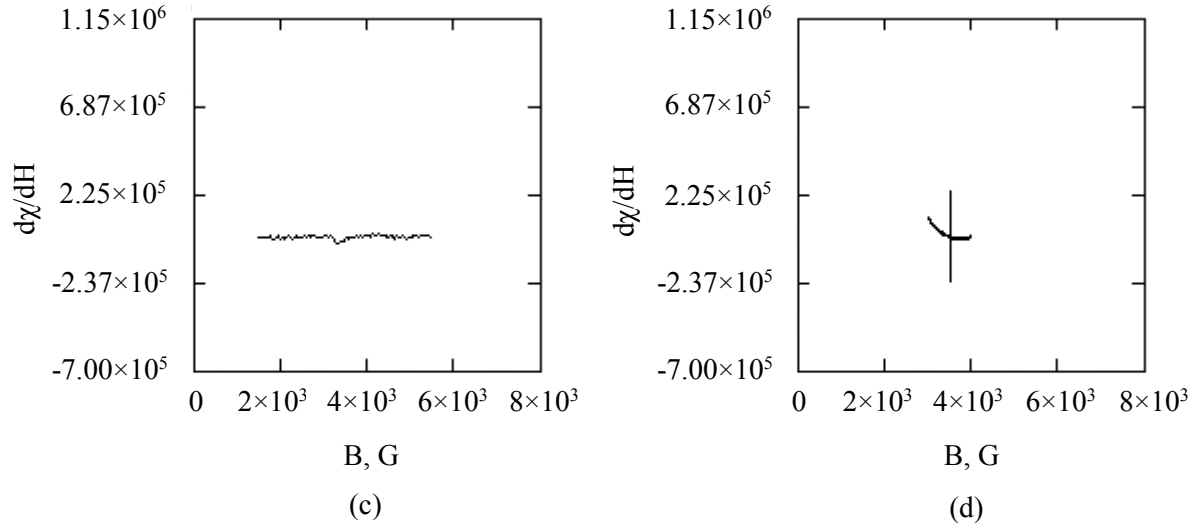

Figure 1. Continued. MR spectra for the yeast *S. cerevisiae* (c), ethmoid bone of silver carp (d).

4. Conclusions

In the paper it has been shown that MR spectroscopy is a power tool to identify ferritin and biogenic magnetic nanoparticles in biological material, which has been confirmed by comparison of MR spectra of different biological material. MR spectrum of biological material of ethmoid bones of salmon and silver carp contains a narrow peak. The appearance of this peak is probably related to the presence of BMN. The spectrum of *E.coli* with ferritin contains much broader peak. The presence of broad peak is characteristic for the samples containing ferritin [7] while the presence of a narrow peak on MR spectra is characteristic feature of monodisperse magnetite nanoparticles.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 644348 (MagIC).

References

[1] Šafařík I, Šafaříková M 2002 *Monatshefte für Chemie/Chemical Monthly* **133** 737
[2] Kirschvink J L, Kobayashi-Kirschvink A, Diaz-Ricci J C and Kirschvink S J 1992 *Bioelectromagnetics* **13** 101
[3] Posfai M and Dunin-Borkowski R E 2009 *Elements* **5** 235
[4] Komeili A 2012 *FEMS Microbiol Rev.* **36** 232
[5] Hudson A J, Andrews S C, Hawkins C, Williams J M, Izuhara M, Meldrum F C, Mann S, Harrison P M, Guest J R 1993 *Eur. J. Biochem.* **15** 985
[6] Hassett R F, Romeo A M, Kosman D J 1998 *J. Biol. Chem.* **273** 7628
[7] Wajnberg E, El-Jaick L J, Linhares M P, Esquivel D M. 2001 *J. Magn. Reson.* **153** 69