International Journal of
Innovative Drug Discovery
e ISSN 2249 - 7609
Print ISSN 2249 - 7617
www.ijidd.com

STUDY OF PROPERTIES FOR ZINC IRON (II) FERRITE NANOPARTICLES

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ABSTRACT

The solubility of zinc ferum (II) ferrite in an acidic media (pH=1.6) was determined using atomic absorption spectrometry method. Such media imitates a composition of human gastric juice. An active zinc ion release of the $Zn_{0.4}Fe_{2.6}O_4$ phase into a solution at 37 ºC and slow release of iron ions (Fe^{2+}) were found. The sample's mass fraction, transferred into a hydrochloric acid solution is: 5.61% of total iron, and zinc iron (II) ferrite -12.1%. The *in vitro* microbiological screening showed that zinc iron (II) ferrite has moderate antimicrobial activity against Gram-positive and Gram-negative microorganisms, Escherichia coli, fungi of the *Candida* genus.

KEY WORDS: Zinc substituted magnetite synthesis, Ferrite, Atomic absorption spectrometric analysis (AAS), Zinc, Gram-negative and Gram-positive microorganisms, Antimicrobial activity.

INTRODUCTION

Increasing the amount of microorganism strains resistant to antibiotics determines the necessity to create new and more effective antibacterial drugs [1-3]. One possible solution to this problem is the modification of drugs containing magnetic filler, which can exhibit simultaneously both antimicrobial activity and be magnetically controlled for prolonged action. The aim of this work was to study the biological properties of the synthesized zinc iron (II) ferrite nanoparticles: establishing of their solubility in the acidic media (pH=1.6), at T=37ºC, the study of antimicrobial activity, which will allow its further use in gastroenterology. For the applications in gastroenterology the zinc ferrite dissolution was studied *in vitro* in a solution simulating gastric juice.

MATERIALS AND METHODS

A chemical condensation was applied to synthesize finely-dispersed nanoparticles of zinc iron (II) ferrite $Zn_{0.4}Fe_{2.6}O_4$ which can be considered as zinc substituted magnetite ($FeFe_2O_4$) with a particle size of about $\langle d \rangle \approx 9.6$ nm.The dissolution kinetics of ferrite samples was investigated in a biological experiment, in accordance with SUPh (Article 2.9.3.) [4-12] under certain conditions : the temperature 37ºC; pH=1.6; an amount and the stomach exposure duration were compatible with a methodology.

By atomic absorption spectroscopy (spectrophotometer "Saturn") in an air-acetylene flame under the following conditions: pressure - 0.2 MPa, the temperature of the flame - 2250 ºC, analytical and calibration signals of the test solutions were established. For the analysis, the most sensitive lines - 213.8 nm for zinc and 248.3 nm for iron were selected. To determine the concentration of Zn and Fe the spike test was applied.

The study of the antimicrobial activity of the ferrite synthesized was conducted in the laboratory of antimicrobial agents SU "IMI of I.I. Mechnikov NAMS of Ukraine" under the supervision of MD, V.V. Kazmirchuk. Initial microbiological screening of new synthetic substances had been done using standard test-strains of Gram-positive and Gram-negative microorganisms that belong to different taxonomic groups: *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *P. aeruginosa* ATCC 27853, *B. subtilis* ATCC 6633, *C. albicans* ATCC 885-653.

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Microbial burden was 5×10^5 CFU/ml related to museum strains.

Antibacterial and antifungal activity of the zinc iron (II) ferrite synthesized was performed by the standard method of successive serial dilutions in nutrient broth according to the order of Ministry of Health of Ukraine from 05.04.2007 № 167 "Determination of the sensitivity of microorganisms to antibiotics" and, accordingly, the methodical recommendations "Study of the specific activity of antimicrobial drugs" (2004) [19]. The minimum inhibitory concentration (MIC) was set as the lowest concentration of the test substance, which inhibits visible culture growth. To determine the minimal bactericidal and fungicidal concentrations (MBC, MFC) the dose crops of cell culture liquid from all tubes on a solid nutrient medium (Mueller-Hinton agar, Sabouraud agar) were performed. During experiments, following controls were done: the growth control of the culture in the medium without the test substances in a solvent (2N HCl); the purity control of microorganism suspension (by plating on non-selective medium) and sterility.

RESULTS AND DISCUSSION

Study of solubility by AAS method allows to determine the solubility of the sample and a transfer of Zn^{2+} and Fe^{2+} ions into the solution, pH of which is 1.6; and the exposure time is 3 hours. Obtained data, given in Table 1, show the active transfer of zinc from $Zn_{0.4}Fe_{2.6}O_4$ phase into the solution and low transfer of iron ions.

Mass fraction of the sample that transferred into a solution of hydrochloric acid is: of the total iron - 5.61%, of the zinc - 6.35%. In general, the mass fraction of zinc iron (II) ferrite, which transferred into a solution of hydrochloric acid, is 12.1% .In the first 90 minutes the highest solubility of the sample than further was noted. At the end of the experiment in the precipitate, which was not dissolved, the Fe_2O_3 phase was found, presumably, iron ions in octahedral positions were not involved in dissolution.

The data of ferrites dissolution, given in Table 1 show moderate stability of samples in acidic media (pH=1.6). The transfer of ions into HCl solution undergoes not stoichiometric in composition of $Zn_{0.4}Fe_{2.6}O_4$, since zinc dissolves more active than iron.

As a part of the biological activity study of the synthesized finely-dispersed zinc iron (II) ferrite *in vitro*, a study of its antimicrobial activity toward reference test cultures that belong to different groups of causative agents for infectious diseases. The antimicrobial activity of the zinc iron synthesized in mcg/ml is given in Table 2.

During the initial microbial screening, moderate bacteriostatic effect of the test substance regarding reference strains of Gram-positive microorganisms (*S. aureus* ATCC 25923 and *B. subtilis* ATCC 6633) in MIC 62.5 mcg/ml was found. Bactericidal activity in the concentration of 125.0 mcg/ml was discovered. A similar antimicrobial effect of zinc iron (II) ferrite synthesized against *E. coli* (MIC and MBC – 62.5 mcg/ml and 125.0 mcg/ml respectively) was specified. Regarding Gram-negative microorganisms and *P. aeruginosa* ATCC 27853, the activity of the substance was not significant.

It should be noted that the test-strain yeasts of *C. albicans* ATCC 885-653 was investigated, he was moderately sensitive toward zinc substituted magnetite. Fungistatic and fungicidal activities of the test sample were observed at a concentration of 125.0 mcg/ml. The growth of microorganisms was observed in all tubes while the solvent control.

Table 1. Data of ferrites dissolution

Dissolution time, min	Solution pH	Concentration			
		Fe^{3+}		Zn^{2+}	
		mol/l	mol/kg	mol/l	mol/kg
30	1.6	$(1.07 \pm 0.02)\cdot10^{-3}$	$1.4\cdot10^{-6}$	$(3.06 \pm0.1)\cdot10^{-3}$	$3.32 \cdot10^{-7}$
60	1.6	$(1.21 \pm 0.04)\cdot10^{-3}$	$1.84\cdot10^{-6}$	$(3.86 \pm0.1)\cdot10^{-3}$	$3.82 \cdot10^{-7}$
90	1.6	$(1.33 \pm 0.05)\cdot10^{-3}$	$2.07\cdot10^{-6}$	$(4.68 \pm0.1)\cdot10^{-3}$	$4.02 \cdot10^{-7}$
120	1.6	$(1.45 \pm 0.06)\cdot10^{-3}$	$2.28\cdot10^{-6}$	$(5.25 \pm0.1)\cdot10^{-3}$	$4.52 \cdot10^{-7}$
150	1.6	$(1.63 \pm 0.06)\cdot10^{-3}$	$2.33\cdot10^{-6}$	$(6.1 \pm0.1)\cdot10^{-3}$	$5.1 \cdot10^{-7}$
180	1.6	$(1.7 \pm 0.20)\cdot10^{-3}$	$2.4\cdot10^{-6}$	$(7.6 \pm0.1)\cdot10^{-3}$	$5.32 \cdot10^{-7}$

Table 2. Antimicrobial activity

Test-strain		Sample		Solvent
		MIC	MBC (MFC)	MIC
1	S. aureus ATCC 25923	62.5	125.0	>500.0
2	B.subtilis ATCC 6633	62.5	125.0	>500.0
3	E. coli ATCC 25922	62.5	125.0	>500.0
4	P. aeruginosa ATCC 27853	250.0	500.0	>500.0
5	C. albicans ATCC 885-653	125.0	125.0	>500.0

CONCLUSION

1. The results of atomic absorption spectrometric analysis showed an active zinc transfer from phase $Zn_{0.4}Fe_{2.6}O_4$ into the solution at a temperature of 37ºC and slow dissolution of iron ions, which are in tetrahedral positions.
2. Dissolution of iron ions in the octahedral positions does not occur.
3. As a result of the atomic absorption spectrometric analysis the mass fraction of Zn=6.35%, and iron Fe=5.61% were determined in the solution. In general, the mass fraction of zinc iron (II) ferrite, which transferred into the hydrochloric acid solution, is 12.1%.
4. The data of ferrites dissolution, given in Table 1 show moderate stability of samples in acidic media (pH=1.6).
5. The iron ions in octahedral positions not interacted with the solution and are dissolved in 3 hours.
6. As a result of the initial microbiological screening the presence of sufficient antimicrobial activity of the synthesized zinc iron (II) ferrite regarding reference strains of Gram-positive (S. aureus ATCC 25923, B. subtilis ATCC 6633), Gram-negative (E. coli ATCC 25922) and fungi of the genus Candida (C. albicans ATCC 885-653) were revealed, which confirms the possibility to recommend it to create new magnetically controlled drugs.
7. Under conditions of the model biomedical experiment a poor solubility of ferrite samples in aggressive acidic media (pH=1.6) was found.
8. The synthesized finely-dispersed zinc iron (II) ferrite possesses moderate antimicrobial activity regarding clinically important Gram-positive, Gram-negative bacteria and yeast-like fungi of the genus Candida, in in vitro experiments.

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