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To the 80th Anniversary of B.I. Ionin

Nanobiocomposite Based on Selenium and Arabinogalactan: Synthesis, Structure, and Application

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Abstract—Nanocomposite of heteropolysaccharide arabinogalactan and elemental selenium (0.54% of Se) has been prepared and studied by means of transmission electron microscopy, UV spectroscopy, and X-ray diffraction analysis. Possibility of the composite application for treatment of bone injury has been estimated.

Keywords: nanobiocomposite, selenium, synthesis, reparative regeneration, basal metabolism, thermography, fracture

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Maintaining the physiological level of selenium in an organism is of vital importance. It is believed that the major biological function of selenium is acting as cofactor of selenium-containing enzymes [1]. Noteworthily, these enzymes are crucial for a cell redox system operating; hence, fundamental vital activity of the cells involved in the reparative processes is dependent on the selenium-containing enzymes activity [2]. The action of selenium-dependent enzymes (in particular, deiodinases and glutathione peroxidase) is directly dependent on selenium supply [3].

However, many geographical regions have been recognized for 30–60% selenium deficiency. Hence, this element should be additionally introduced into the organism externally. Metabolism of inorganic and organic selenium is remarkably different [4].

In the natural conditions, selenium is majorly received by human and animals in the form of selenium-containing amino acids. Activity of nanosized selenium has been scarcely studied so far. In particular, it has been shown that nanosized red selenium is less toxic and more biologically active as compared to inorganic selenium compounds [5, 6] as well as its organic forms [7, 8].

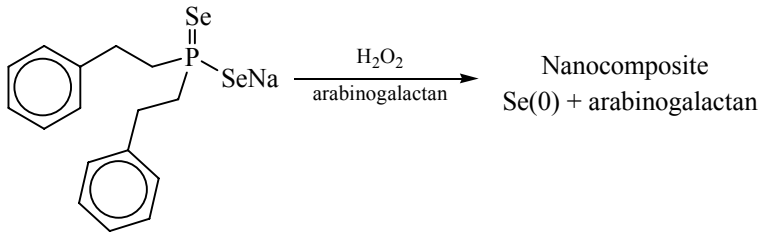
Herein we report on preparation and structure elucidation of a novel nanobiocomposite based on selenium and arabinogalactan; moreover, we discuss the possibilities of its application for local treatment affecting the reparative process under conditions of bone injury.

Arabinogalactan was chosen as a scaffold for the composite preparation due to the polysaccharide water solubility and biocompatibility allowing its application in nanocomposite biomedical systems [9–15].

The nanocomposite was prepared via oxidation of readily available sodium bis(2-phenylethyl)diselenophosphinate [16] with hydrogen peroxide in aqueous solution in the presence of arabinogalactan stabilizing the formed selenium(0) nanoparticles (Scheme 1).

The prepared nanocomposite was a red-orange powder, readily water-soluble. The electronic absorption spectrum of parent arabinogalactan contained the bands at 199 and 287 nm assigned to the aldehyde end groups of carbohydrate units of the polysaccharide.

Scheme 1.



The electronic absorption spectrum of the nanocomposite revealed slight absorbance at 926 nm, a strong band at 600–190 nm, and weaker shoulders at 230–221 and 204–197 nm, characteristic of nanosized selenium(0) [17].

The X-ray diffraction analysis of the nanocomposite revealed the amorphous halo typical of arabinogalactan [11]; however, the expected reflection pattern of crystalline selenium(0) [17] was not observed. Evidently, that could be due to either amorphous structure of the selenium nanoparticles or the extremely small particles size (a known effect of the reflections broadening could cause the signals weakening down to the baseline level).

The electron microscopy observations revealed that the composite consisted of arabinogalactan globules covered with selenium particles, the latter being indeed as small as 2–3 nm.

The animal models study revealed that local administration of the prepared nanocomposite at the region of injury (perforated fracture of tibial bone) had practically no effect on the respiratory parameters of basal metabolism (body temperature, oxygen consumption, and carbon dioxide evolution). However, temperature profile of the treated tissue was changed evidencing about bioavailability of the composite. The composite administration enhanced the metabolism processes due to the presence of additional selenium source. The observed effect was fairly prolonged (up to 3 weeks) thus pointing at the possibility to arrange a local source of selenium via intraosseous injection of the nanocomposite.

EXPERIMENTAL

The nanocomposite preparation. 1.00 g of arabinogalactan was dissolved in 30 mL of distilled water, and then 0.08 g of sodium bis(2-phenylethyl) diselenophosphinate was added. The reaction mixture was stirred during 3 h at 35°C, and then 1 mL of 30 wt % aqueous solution of hydrogen peroxide was added. The mixture was stirred during 1 h at the same temperature, and then poured in ethanol. The prepared red-orange powder was repeatedly washed via decanting, filtered, and dried in vacuum to constant mass.

Selenium content in the nanocomposite was of 0.54% as determined by titration. The prepared composite was studied by means of transmission electron microscopy (TEM-410) and UV spectroscopy (Shimadzu UV-1800). X-ray diffraction analysis was performed using a Bruker D8 Advance diffractometer equipped with Goebel mirror (CuK_α radiation).

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