RESEARCH ARTICLE

Preparation of Selenium Nanoparticles with Mechano-sonochemical Methods

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Abstract

Aim: Nanotechnology and nanomedicine revolutionized the pharmaceutical market, medicine, and biology. The simple size comparison gives an idea of using nanoparticle as very small probes that would allow us to observe the cellular machinery without introducing too much interference. "Nanosizing" drugs decrease toxicity and reduces the needed dose. Nanoparticles are used for site-specific drug delivery, imaging, treating illnesses, and diseases such as cancer, neurodegenerative disorders, ocular diseases, respiratory diseases, and diabetes mellitus. Recent studies indicate the positive impact of selenium nanoparticles on different organ systems. They have antioxidant, antimicrobial, anti-carcinogenic properties, and selenium nanoparticles characterized by good permeability in tissues and low toxicity. Nowadays, there are different ways of preparing nanoparticles, but most of them are related to difficult, toxic, and expensive procedures. **Materials and Methods:** Pure selenium metal powder was used and synthesized nanoparticles were characterized *by* JEOL JSM-6510 LV scanning electron microscope (SEM), Zeiss Ultra 55 SEM, and JOEL JEM-100SX transmission electron microscope; also by dynamic light scattering (Thermo Scientific Nicolet iS50 - Fourier-transform infrared spectroscopy [FTIR]) and Malvern Instruments Zeta Sizer Nano ZS. To reduce the size of the selenium powder, we used planetary ball mill DECO-PBM-V-0.4L and Ultrasonic Homogenizer UZDN-1 U4.2. **Results and Discussion:** Pure selenium grinded powder was characterized in JEOL JSM-6510 LV SEM and wet grinded in Deco planetary ball mill further size reduction to 2–10 µm was confirmed by SEM. Selenium powder suspension was irradiated using ultrasonic homogenizer and characterized for intensity and size of nanoparticles with dynamic light scattering FTIR. Average Zeta potential of -35.05 mV has been recorded. Toxic dose of 5000 mg/kg of selenium nanoparticles has been established as per accordance to OECD guidelines. **Conclusion:** Safe, simple, and cost-effective SeNPs have been developed for the effective treatment of disease such as diabetes with opening of new prospective further in nanotechnology and nanosized drug delivery system.

Key words: Nanoparticle synthesis, selenium nanoparticles, selenium metal powder

INTRODUCTION

Nanomedicine is a relatively new, but rapidly developing field of medicine that uses the latest achievements of nanotechnology and deals with extremely small objects(so-called nanoparticles) comparable with sizes of molecules. Nanoparticles provide a particularly useful platform, demonstrating unique properties with potentially wide-ranging therapeutic applications. Application of nanoparticles in biology is certainly a burgeoning one, with the estimated number of papers in the area (based on Web of Science) rising from 11 in 1991 to nearly 10,000 in 2007[1] since 2011 era of nanoparticles and nanotechnology begins.[2]

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Received: 07-06-2018
Revised: 22-06-2018
Accepted: 29-06-2018

Among pharmaceutical nanosystems two basic types - nanomaterials and nanodevices can be defined. Nanomaterials are subclassified into nanocrystalline and nanostructured materials. The latter consists of nanoparticles, dendrimers, micelles, drug conjugates, metallic nanoparticles, etc.[Figure 1].[3]

Nanoparticles are designed and used for therapeutics, diagnostics, and as biomedical tools for research. With the help of nanotechnology, its now possible to provide therapy at a molecular level which may further help in treating and pathogenesis of the disease.[4]

The simple size comparison gives an idea of using nanoparticle as very small probes that would allow us to spy at the cellular machinery without introducing too much interference.

Nanoparticles are used for site-specific drug delivery, imaging, treating illnesses, and diseases such as cancer, neurodegenerative disorders, ocular diseases, respiratory diseases, HIV/AIDS, diabetes, and drug detoxification.[5-11]

Selenium is one of the essential trace element in the body due to its antioxidative as well as pro-oxidative effect and has great importance in nourishment and medicine. Like other nanoparticles, selenium nanoparticles would have some unique mechanical, optical, electrical, biologic, and chemical properties as compared with bulk materials. It has been reported that the selenium nanoparticles have high biological activities and low toxicity.[12]

Recent studies indicate the positive impact of selenium nanoparticles on different organ systems. They have antioxidant, antimicrobial, anti-carcinogenic properties, and selenium nanoparticles characterized by good permeability in tissues and low toxicity; peroral administration is possible as well. It has been confirmed that selenium can improve the activities of the selenoenzymes such as selenium-dependent glutathione peroxidases which act as a function of redox centers and prevent free radicals from damaging cells and tissues *in vivo*. It should be emphasized an important role of selenium, as a microelement in the human body, and its antioxidative and anti-carcinogenic properties. Selenium deficiency causes arrhythmias, heart failure, cardiomegaly, cardiomyopathy, thromboembolism, and myocardial infarction. Selenium deficiency decreases the protective ability of the body to free radicals.[20-30]

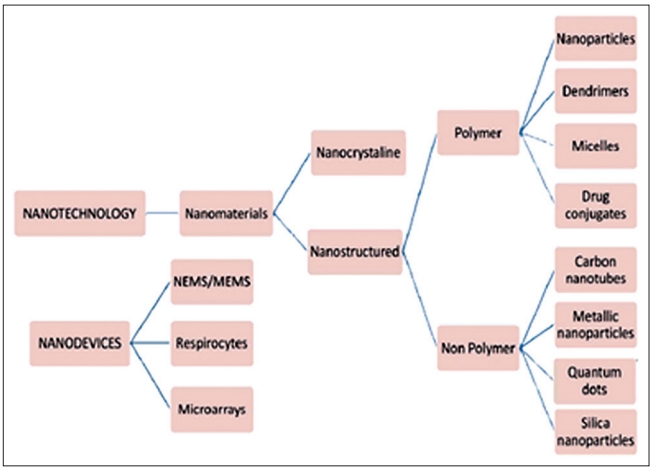

Figure 1: N1 schematic diagram of various types of pharmaceutical nanosystems

According to the conducted studies, the amount of selenium and GPx is less in people with diabetes mellitus in comparison with healthy ones. It was found that an amount of Selenium and GPx decreases during the progression of diabetes.[13-22] GPx deficiency could have a key role in the pathogenesis of diabetes mellitus due to increased oxidative stress. Increased production of free radicals and reduction of antioxidant activity the person affected with diabetes mellitus requires administration of a relatively large number of antioxidants in comparison with healthy one.[23]

The nanostructured materials have been synthesized by different methods including inert gas condensation, mechanical alloying, spray conversion processing, plastic deformation, electrodeposition, rapid solidification from the melt, physical vapor deposition, chemical vapor processing, coprecipitation, sol-gel processing, sliding wear, spark erosion, plasma processing, auto-ignition, electrodeposition, chemical precipitation and coprecipitation, laser ablation, hydrothermal pyrolysis, thermophoretic forced flux system, quenching the melt under high pressure, and biological templating. There is a range of methods of producing metallic nanosized materials including radiation methods thermal decomposition, vapor deposition, reduction in microemulsions, and chemical reduction methods. However, most of these techniques tend to be expensive and time-consuming.[24-30] Simple and cost-effective method of preparation of selenium nanoparticles with good catalytic activity is still a challenge.[31]

The aim of our study was to prepare selenium nanoparticles using two simples: Mechanical and Sonochemical methods. Prepared nanoparticles will be used in diabetic rats. After it was confirmed the role of free radicals in the pathogenesis of diabetes and was suggested application of antioxidants to prevent late complications and treatment of diabetes mellitus.

MATERIALS AND METHODS

Research works where conducted in Tbilisi State University/A. Natishvili Institute of Morphology and Tbilisi State University/E. Andronikashvili Institute of Physics. We used pure selenium metal powder. Selenium powder and synthesized nanoparticles were characterized *by* JEOL JSM-6510 LV scanning electron microscope (SEM), Zeiss Ultra 55 SEM, and JOEL JEM-100SX transmission electron microscope (TEM); also by dynamic light scattering (Thermo Scientific Nicolet

iS50 - Fourier-transform infrared spectroscopy [FTIR]) and Malvern Instruments Zeta Sizer Nano ZS. To reduce the size of the selenium powder, we used planetary ball mill DECO-PBM-V-0.4L and Ultrasonic Homogenizer UZDN-1 U4.2.

RESULTS AND DISCUSSIONS

For grinding, we used pure selenium metal powder [Figure 2] 50–80 μm size. The powder was characterized in JEOL JSM-6510 LV SEM, supplied with X-Max N20 detector [Figure 3].

This powder was grinded in Deco planetary ball mill will aluminum jars and balls (DECO-PBM-V-0.4L). In each jar, we put 40 g selenium powder and added 40 ml sterile water for injection. Wet grinding was provided by bi-direction milling at 800 rpm. After 3 h bi-direction grinding, we have examined the material in same SEM. Size has reduced to 20 μm [Figure 4].

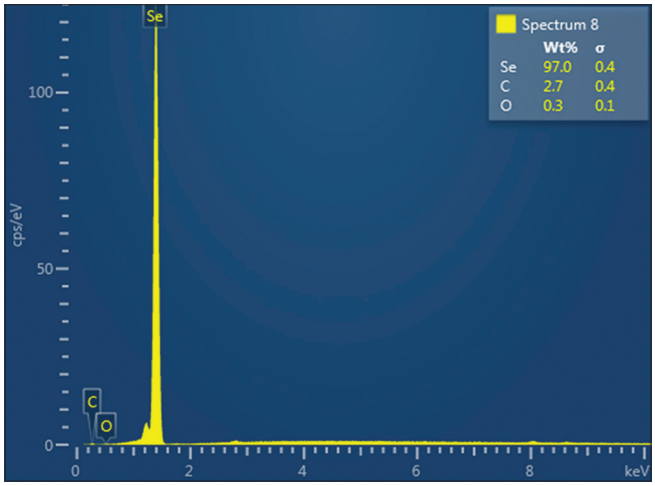

Figure 2: Selenium power

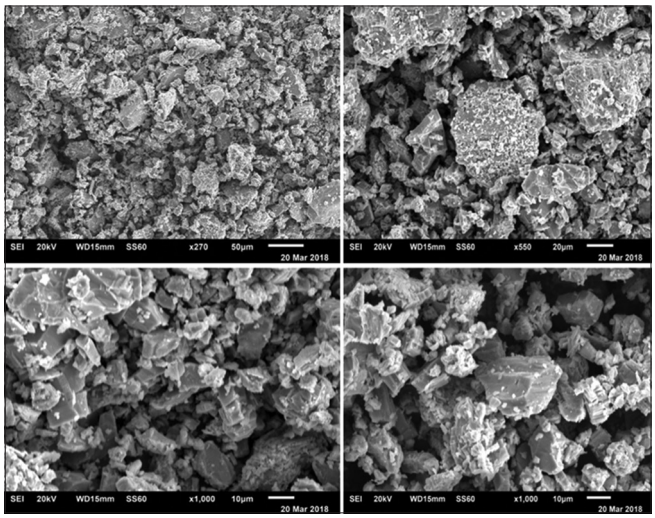

Figure 3: Pure selenium power JEOL JSM-6510 LV scanning electron microscope

We continued bi-direction wet grinding 800 rpm for 1 h the size was reduced to 2–10 μm [Figure 5].

After grinding to 40 g powder, we have added 360 ml sterile water for injection and got 10% selenium suspension. To reduce the size, we used sonochemical method - ultrasonic irradiation.

We used Ultrasonic Homogenizer UZDN-1 U4.2. Selenium suspension was irradiated by 250W ultrasonic homogenizer for 20 min. This suspension was characterized by Dynamic Light Scattering (Thermo Scientific Nicolet iS50-FTIR, for understanding intensity, and size of nanoparticles), SEM (Zeiss Ultra 55 SEM) [Figures 6 and 7].

We have identified the average zeta potential -35.05 (Malvern Instruments Zeta Sizer Nano ZS) [Figure 8].

To reduce size we have irradiated once again selenium nanoparticle suspension with an ultrasonic homogenizer for

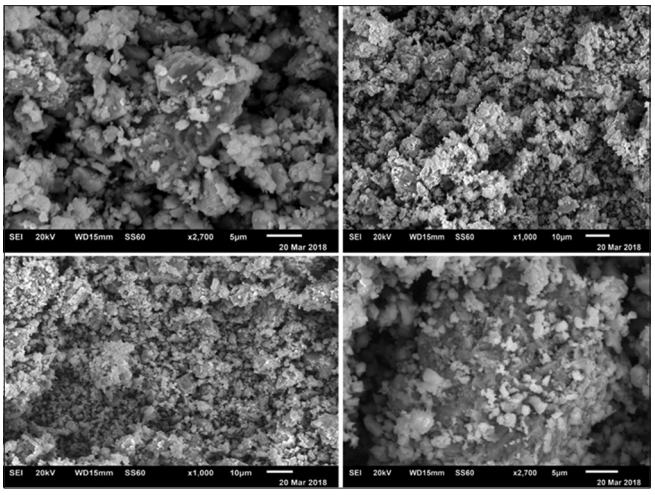

Figure 4: Selenium power after 3 h grinding scanning electron microscope

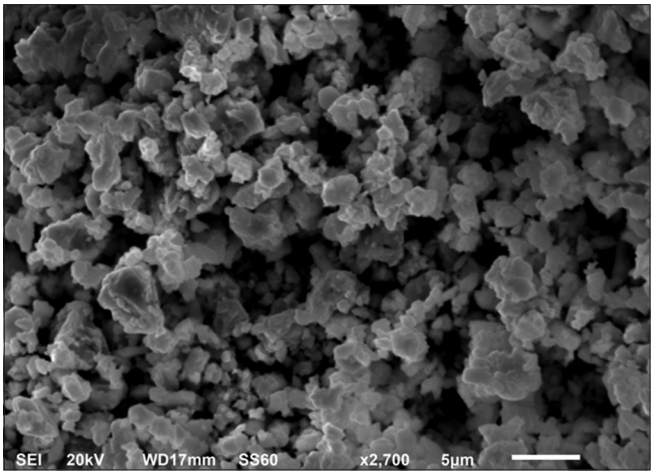

Figure 5: Selenium powder after 4 h grinding scanning electron microscope

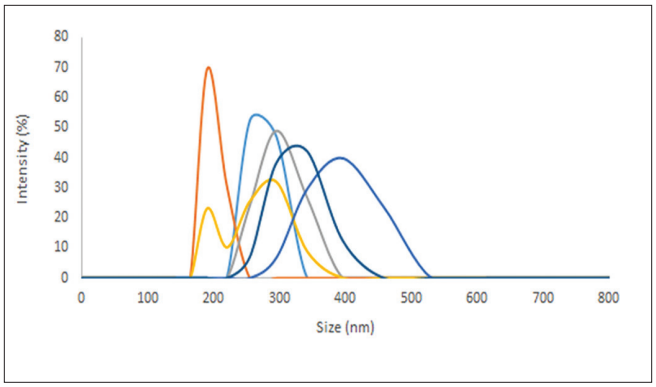

Figure 6: Intensity of SeNPs

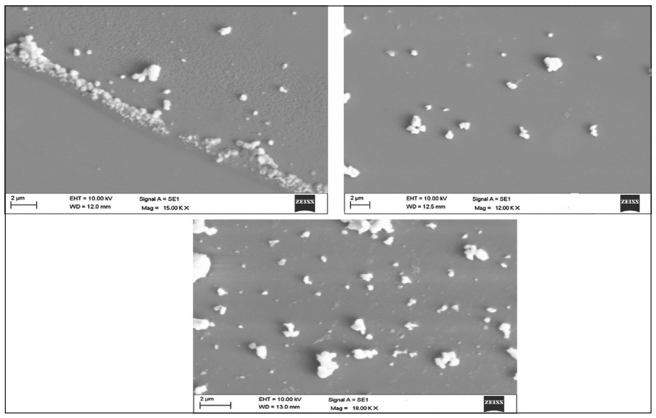

Figure 7: SeNPs after ultrasonic irradiation

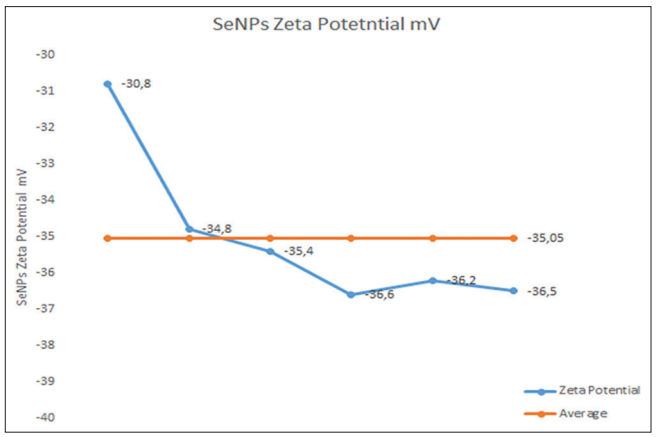

Figure 8: SeNPs Zeta Potential MV

20 min 250W, it was observed in -TEM (JOEL JEM-100SX) size reduced <100 nm [Figure 9].

We attempted to establish the toxic dose of Selenium nanoparticle suspension in rats. The experiment was carried out in accordance with the OECD guidelines (OECD GUIDELINE FOR TESTING OF CHEMICALS #423 - Acute Oral Toxicity - Acute Toxic Class Method. Strasbourg. 2001). Selenium suspension appeared to be safe even at maximal dose 5000 mg/kg.[32-47]

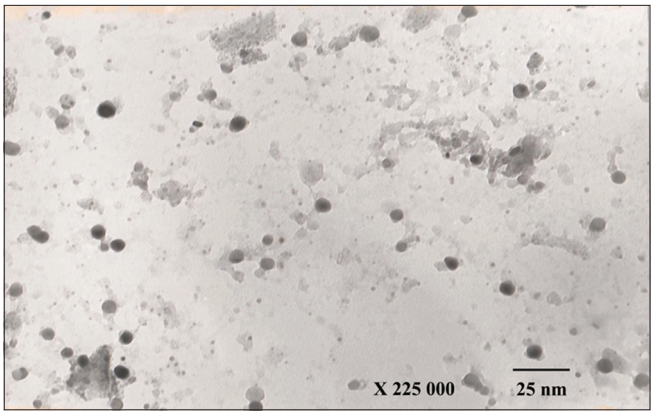

Figure 9: SeNPs after 40 min ultrasonic irradiation transmission electron microscope

CONCLUSION

We have introduced a simple, cost-effective, and cheap way to synthesize SeNPs, which can be used for treatment different disease including diabetes. Nanotechnology-enabled drug delivery is opening prospective future in pharmaceutics. Nano-sized drugs have lower drug toxicity, reduced cost of treatments, improved bioavailability, and an extension of the economic life of proprietary drugs.[48]

ACKNOWLEDGMENTS

This work was supported by Shota Rustaveli National Science Foundation, call for Ph.D. fellowships. The Project name: Formation of Selenium Nanoparticles Suspension and its Efficiency in Treatment of Diabetes Mellitus-Induced Vascular Complications in Experimental Model. Grant number (NPhDF2016_92).

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Source of Support: Nil. **Conflict of Interest:** None declared.