Preparation of silver core nanoparticles with polysaccharide shell

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The objective of the present study was to obtain silver core nanoparticles coated with dextran shell. In the described method dextran plays role of reductive and protective agent and also functionalisation ligand. Our research was aimed at nanoparticles synthesis at 37°C. It is the human body temperature, which is safe for temperature-sensitive drugs (proteins). In the presented work the time of reaction, dextran molecular weight and its chemical functionalisation was investigated. Particles were characterized by Nanosight and SEM, their UV–Vis spectroscopic absorption properties were also determined. Nanoparticles with diameter less than 95 nm with relatively narrow size distribution were obtained. Our work demonstrated that it was possible to obtain nanoparticles in 37°C without using any harmful reagents.

Keywords and phrases: silver nanoparticles, dextran, polyaldehydodextran.

Introduction

Nanoparticles with cores composed of inorganic materials such as noble metals have vast potential for application in many different areas of biomedicine. Applications of nanoparticle include drug carriers, labeling and tracking agent, vectors for gene therapy, hyperthermia treatments and magnetic resonance imaging (MRI) contrast agents. Requirements that are imposed on such nanoparticles are predictable and controllable effects of drug delivery with minimum toxicity and side effects. These criteria can be controlled by carefully chosen shells materials. Shells should provide stabilization, specific targeting and recognition of biochemical species. Application of polysaccharide improves biocompatibility and reduces toxicity, as they completely degrade in vivo.

Dextran is a natural macromolecule composed of α-(1-6) linked D-glucose units with varying branches depending on the dextran-producing bacterial strain. Dextran is a hydrophilic and water-soluble substance, inert in biological systems and which does not affect cell viability. Because of these properties, dextran solutions have been used for many years as blood expanders to maintain or replace blood volume, and studied for uses a carrier system for a variety of therapeutic agents. Recent studies revealed that the use of dextran as prodrugs component reduces toxicity, offers sustained release and influences the biodistribution properties of various drugs [1–4].

Methods

Nanoparticles were obtained with one step synthesis method [5]. Nanoparticles with Ag core have been synthesized in aqueous solution. This methods provide a water-dispersible nanoparticles which are necessity for the application in biological systems. Shells have been made from dextran and polyaldehyde-dextran, both of molecular weight 40 and 70 kDa (Nobilus). Polyaldehyde-dextran was obtained by the periodate oxidation method [6]. Approximately 10 g of dextran was dissolved under stirring in 200 ml of distilled water. Then, 2.3 g sodium periodate (Fluka) was added. The reaction was carried on in dark at 24°C. After 1 h, the reaction was stopped and oxidized dextran solution was dialyzed against distilled water. After freeze-drying pure polyaldehyde-dextran with 5% degree of oxidation was obtained. Hydroxylamine hydrochloride (Fluka) solution was used for determination of oxidation degree [7]. Unreacted dextran samples were used as controls.

The dextran-based nanoparticles were synthesized as follows: dextran or polyaldehyde-dextran were dissolved in 10 ml of deionized water to reach the desired concentration and 100 µl of 0.1 M $AgNO_3$ (Fluka) was added. This mixture was stirred at 37°C for 1, 3 and 24 h. One sample on nanoparticles was also obtained by boiling for 30 min, to compare the results. The final concentration of dextran and polyadehyde-dextran are shown in Table 1.

Table 1. The ratio of reagents in the synthesis of Ag-dextran and Ag-polyadlehyde-dextran nanoparticles.

Sample no.	Dextran concentration [mg/ml]	Polyaldehyde--dextran concentration [mg/ml]	$AgNO_3$ [mM]
1	10	10	1
2	6	6	1
3	5	5	1
4	4	4	1
5	2,5	2,5	1

The sizes of the nanoparticles were determined using a NanoSight device with 405 nm laser beam. Also UV--Vis absorption spectra were collected. Scanning electron microscopy (SEM) (Phenom Fei) was also used to observe the morphology of the obtained nanoparticles.

Results and Discussion

The color of the suspension was changing from white to dark violet, when the reaction was carried on. The distinctive colors of colloidal silver appear due to plasmon absorbance. Incident light creates oscillations in conduction electrons on the surface of the nanoparticles and electromagnetic radiation is absorbed [8]. The color of the solution and the maximum absorbance are related to the size of nanoparticles. This observation has been confirmed by UV–Vis absorbance spectra which are shown in Fig. 1. The absorbance maximum was located at 420.5, 429.0, 430.0 and 431.0 nm for samples 1 to 5. These data demonstrate that increasing the molar ratio of dextran results in a blue-shift of absorbance spectra. This result indicates that the size of the nanoparticles formed varies with the concentration of dextran, which acts as a reductive agent as well as a stabilizer.

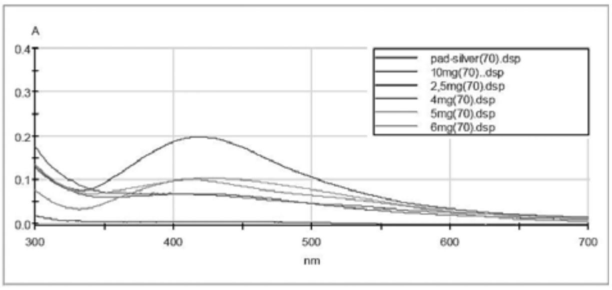

Fig. 1. UV-Vis absorbance spectra of silver-polyaldehyde--dextran nanoparticles.

In order to investigate the diameter of nanoparticles an analysis by the NanoSight device was performed. The obtained results are summarized in Table 2. A fresh mixture of dextran with silver was used as a control. The diameter of obtained nanoparticles are mostly dependent on dextran concentration. At the concentration of 2.5 mg/ml, nanoparticles size is the same as for the control, and reach among 60–65 nm. Increasing the dextran concentration, increases the diameter of nanoaprticles. For 70 kDa dextran at 10 mg/ml concentration the largest naoparticles diameter of 90 nm is obtained. While the size of formed nanoparticles increases, the concentration decreases. This observation is shown in Fig. 2. Obtained nanoparticles exhibit narrow size distribution.

All nanoparticles made from the dextran of 70 kDa have a diameter greater than 40 kDa. This situation is probably caused by long chain of dextran which are adsorbed at the surface of silver core. We also investigated the impact of dextran oxidation on nanoparticles diameter. Obtained results showed that the employment of polyaldehyde-dextran increases nanoparticles diameter. Rise in nanoparticles diameter is caused by appearance of aldehyde groups in oxidize dextran. Presence of aldehyde groups improves formation of acetal bonds between the dextran chains which causes expansion of the shell and of the whole nanoparticle diameter.

Table 2. The ratio of reagents in the synthesis of Ag-dextran and Ag-polyaldehyde-dextran nanoparticles after 24 h an results for control samples.

Concentration [mg/ml]	Dextran				Polyaldehyde-dextran			
	40 kDa		70 kDa		40 kDa		70 kDa	
	37°C	100°C	37°C	100°C	37°C	100°C	37°C	100°C
10	80	80	83	82	81	80	88	84
6	76	78	80	78	80	77	80	81
5	72	72	73	71	72	75	74	80
4	70	69	70	68	67	71	71	72
2,5	61	67	67	65	66	65	65	68

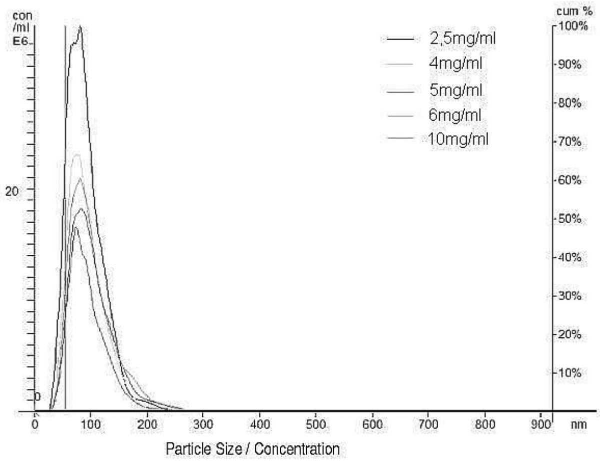

Fig. 2. Diagram of nanopacticles diameter after 24 h reaction (Nanosight).

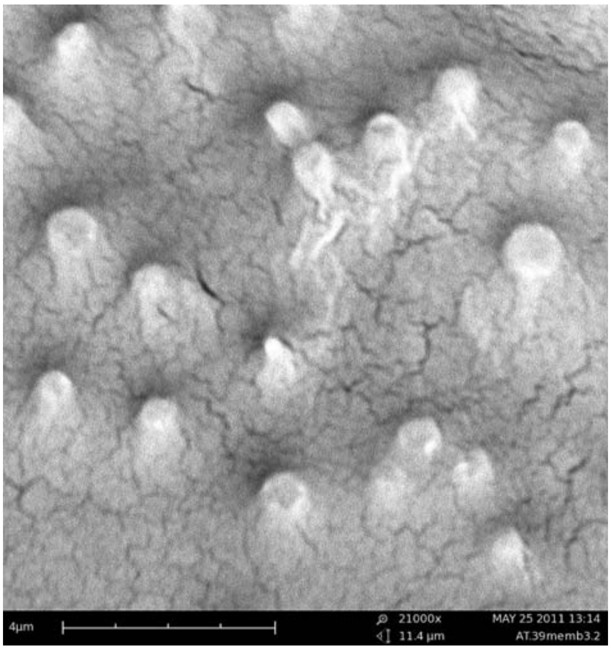

Fig. 3. The SEM images of silver-dextran nanoparticles.

We have also investigated the influences of the time of the reaction on the nanoparticles diameter formed in 37°C. With the increasing of the reaction time the bigger of nanoparticles sizes was observed. This may be caused by the production of bigger core (longer time for diffusional growth) or thicker shell — longer time for shell growth.

SEM studies reveal the regular shape of formed nanoparticles (Fig. 3). The diameter obtained from SEM measurement were about 300 nm, which are larger than diameters observed by NanoSight. This can be explained by the adhesion of the unreacted dextran chains during freeze-drying and then covering by the gold layer during sputtering.

Conclusions

Simple technology of silver core nanoparticles coated with dextrane shell was presented. Particles were formed directly in one step process at mild temperature without using any organic solvents or surfactants. Obtained nanoparticles have a stable structure. It was found out that the size of nanoparticles depended significantly on the molecular weight and dextran concentration. Simplicity and mild condition of the process allows the application of this process to produce drug containing nanoparticles. Dextrane aldehyde is also very reactive and various drugs or antibodies can be easily bonded to such a shell.

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