SPECTRAL ANALYSIS OF OBTAINED QUANTUM CARBON DOTS FROM FOOD PRODUCTS

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Abstract

The article describes the preparation and testing of optical properties of carbon quantum dots. Optical properties were tested using a UV-VIS spectrophotometer and spectrometer. The maximum absorbance was determined in the range of \( \lambda \sim 377 \) to \( \sim 408 \) nm. All solutions obtained showed an emission corresponding to the wavelength in the green light range. Furthermore, the effect of solution concentration on the optical properties of carbon quantum dots was investigated.

Keywords: quantum carbon dots; nanoparticles; UV–VIS absorption.

Introduction

Carbon quantum dots (CQDs) are a new class of nanomaterials obtained in 2004. Since their discovery, their popularity has been steadily increasing, which is reflected in the increasing number of publications with the word "carbon dots" in the title [1-3]. Since the first receipt of carbon quantum dots, many new synthesis methods and properties have been described, and their use has been demonstrated in many different areas. In opposition to semiconductor quantum dots, CQDs aren’t toxic. The toxicity of traditional carbon quantum dots is due to the use of heavy metals in their production. Therefore, the use of QDs in clinical trials may be problematic [4-6]. Moreover, another disadvantage with semiconductor quantum dots is the costly and often polluting the environment synthesis methods. Therefore, CQDs can be an alternative for them because they can be produced in an environmentally friendly and inexpensive way [4,7]. CQDs synthesis methods are divided into two main groups: bottom-up and top-down. Bottom up methods include: microwave synthesis, thermal decomposition, hydrothermal synthesis, plasma treatment. While, top-down methods include ultrasonic synthesis, oxidizes electrochemical nannies, chemical oxidation, arcing. The first of the methods usually used to synthesize CQDs utilize an impact of energy on a carbon source. An example of such a method is laser ablation. However, the nanoparticles obtained in the above manner weren’t fluorescent. These particles began to show fluorescence only after surface functionalization [2,8]. Replacement to the synthesis methods requiring the consumption of a large amount of energy is the method of synthesis in hydrothermal conditions. The synthesis is carried out in an aqueous solution of appropriate compounds, at high temperature, under high steam pressure. Furthermore, this method is considered simple and cost-effective due to the use of cheap apparatus and the possibility of obtaining CQD from practically any biomass. CQDs are composed of a carbogenic core and crystalline or amorphous parts. They also have functional groups on their surface [3-4,9-10]. They are usually oxygen groups, what is the causa that CQD gain good solubility in aqueous solutions [3]. Excitation-dependent photoluminescence is another and probably most commonly used property of CQD. However, the exact fluorescence mechanism of these

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nanoparticles is not yet fully understood [4,11]. CQDs show absorbance in the UV region with the tail extending to the visible area [3,12-13]. These nanoparticles are used, among others in bioimaging and as biosensors. Due to, multi-color emission-dependent emission and high photostability, biosensors based on CQDs have been created for visual monitoring, among others copper, potassium iron and nucleic acids [14-15]. Moreover, chemical sensors using CQDs to detect Hg$^{2+}$ mercury ions have also been developer [16].

In this paper, CQD was obtained in hydrothermal conditions from gelatin and a hypoallergenic infant formula replacement. Gelatin is a virtually colourless and tasteless water-soluble protein prepared from collagen and used in food preparation. The above food products were used due to the high content of amino acids, which may affect the quantum efficiency of the CQDs obtained [17].

Experimental

Four samples were prepared as follows: samples 1 2 and 3 were prepared from gelatin, while sample 4 from infant milk replacer. Sample 1 was prepared from 13.2g of gelatin dissolved in 40ml distilled water with the addition of 2.5ml spirit vinegar. Sample 2 was prepared from 1g of gelatin dissolved in 40ml distilled water with the addition of 1ml spirit vinegar. Sample 3 was prepared from 1g of gelatin dissolved in 40ml distilled water and sample 4 was prepared with 4.5g of hypoallergenic milk and 30ml of distilled water. Secondly, the solutions were placed in an autoclave - stainless steel vessel with a teflon liner - and placed in the oven. Sample 1 was heated for 6h at 180°C. Sample 2 and 3 were heated for 3h at 200°C. Sample 4 was and heated for 3h at 180°C. Finally, the vessel was cooled to room temperature. Solutions were subjected to multi-stage filtration using ultrasounds, a centrifuge and PES filters. Moreover, solutions were washed with dichloromethane to remove the unreacted organic moieties Sample 1 was diluted three times, five times and ten times.

Results and discussion

The UV-VIS Cary 100 Bio spectrophotometer from Varian and the Al-Prof SM1 Hm spectrometer were used to characterize the optical properties of carbon quantum dots. UV-VIS spectra of all samples are shown in Fig. 1.

![Fig. 1. UV–VIS absorption spectrum](image)

The absorbance spectrum of sample 1 diluted three times shows a broad peak in the range of ~ 368 nm to ~ 440 nm, with a maximum at 408nm. The maximum absorbance of sample 1 diluted five times is 397 nm, the absorbance peak has a smaller range than that of the sample
diluted three times, i.e. from $\sim 368\text{nm}$ to $\sim 420\text{nm}$. Sample 1 diluted ten times had an absorbance peak extending less than that of the previous two solutions, ranging from $\sim 368\text{nm}$ to $\sim 400\text{nm}$, with a maximum absorbance of 380nm. For that reason, it can be assumed that the concentration of the tested solution affects the shift of the absorption band. In the above cases, it was observed that in the case of solutions with lower concentration, the absorption band shifts in the direction of shorter waves. The absorbance spectrum of sample 2 shows a broad peak in the range of $\sim 368\text{nm}$ to $\sim 395\text{nm}$, with a maximum absorbance of 377nm. The absorbance spectrum of sample 3 shows a wide peak in the range close to sample 2, i.e. from $\sim 368\text{nm}$ to $\sim 395\text{nm}$, with a maximum, which, as in sample 2, is 377nm. The absorbance spectrum of sample 4 shows a broad peak in the range of $\sim 368\text{nm}$ to $\sim 400\text{nm}$, with a maximum of 380nm. Based on the range of absorbance spectra and its maximum values, it can be assumed that there was an electronic transition from the $n$-binding orbital to the $\pi^*$ anti-binding orbital in all of the above samples.

Using the Al-Prof SM1 Hm spectrometer, the maximum CQD excited emission was determined. The results are presented in Fig. 2-7.

![Fig. 2](image1.png)  
**Fig. 2.** Sample 1 diluted three times: a) photoluminescence emission spectrum, b) sample under UV light

![Fig. 3](image2.png)  
**Fig. 3.** Sample 1 diluted five times: a) photoluminescence emission spectrum, b) sample under UV light

![Fig. 4](image3.png)  
**Fig. 4.** Sample 1 diluted ten times: a) photoluminescence emission spectrum, b) sample under UV light

![Fig. 5](image4.png)  
**Fig. 5.** Sample 2: a) photoluminescence emission spectrum, b) sample under UV light
Figures 2-7 presents the photoluminescence spectra of the solutions and their photos in ultraviolet light. The maximum emission of excited carbon quantum dots was determined from ~498nm to ~558nm. Based on the above photoluminescence spectra, it can be assumed that the concentration of the solution may affect the shift of the photoluminescence spectrum. In the above cases, it was observed that the lower the concentration of the solution, the more the spectrum is shifted towards short waves. In each of the solutions obtained, the maximum emission corresponds to the wavelength characteristic of green emission.

Conclusions

Based on the performed spectrophotometric, spectrometric and literature data, it can be assumed that carbon quantum dots from gelatin and infant formula replacement were obtained. The effect of solution concentration on optical properties was also investigated. Based on the obtained UV-VIS spectra, it can be assumed that the concentration of the solution affects its optical properties. The sample with the highest concentration showed a broad peak with a maximum $\lambda_{\text{max}} = 408$ nm, while the UV-VIS spectrum of the sample with a lower concentration showed a peak in the lower wavelength range and with the maximum shifted towards ultraviolet waves, $\lambda_{\text{max}} = 380$ nm. The excitation of synthesized quantum carbon dots was induced by a UV lamp emitting light in the range from 360 to 370 nm.

References


Received: June 03, 2020
Accepted: July 09, 2020