MATERIALS FOR BIOMEDICAL APPLICATIONS

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CDTE QUANTUM DOTS–ALBUMIN BIONANOCOMPLEX: GENOTOXIC POTENTIAL AND BIOIMAGING APPLICATION IN A *DROSOPHILA MELANOGASTER* MODEL

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Background: Research on semiconductor nanocrystals, known as quantum dots (QDs), and their applications in biomedical research, bioimaging, and diagnostics is evolving rapidly. Although CdTe QDs exhibit remarkable optical properties, their practical application is limited by their toxicity. As a result, research is ongoing to reduce the toxicity of QDs by coating them with inert shells or by forming complexes with biomolecules.
Objectives: Therefore, the aim of our study was to evaluate the genotoxic potential of the bionanocomplex of CdTe QDs with human serum albumin (HSA) as a safe and promising tool for fluorescence bioimaging *in vivo*, using *D. melanogaster* as a model.
Materials and Methods: CdTe QDs were obtained by chemical colloidal method in the aqueous phase and conjugated with HSA to create CdTe QDs-HSA bionanocomplex. The toxicity and genotoxicity of the QDs were evaluated in relevant tests on the *D. melanogaster Oregon R* strain. To visualize of QDs a fluorescence microscopy was applied. The data were subjected to statistical analysis, with differences deemed significant at $p<0.05$.
Results and Discussions: It was established that bionanocomplexes, similar to CdTe QDs, penetrated the germline cells, and were transferred to the eggs and larvae, as confirmed by histological preparations. In the muscles of the imago, rare CdTe QDs and their HSA conjugates were detected. The tested QDs types did not cause toxicity in adults after a 3-day exposure period, nor did they decrease their reproductive capacity or cause a genotoxic effect in the DLM test at the embryonic stage. Upon larval feeding, both types of QDs exhibited a teratogenic effect. Unlike CdTe QDs, the bionanocomplex induced phenotypic anomalies in imagos at a significantly lower frequency (2.3 times) and did not cause a reduction in their eclosion compared to the control group ($p>0.05$).
Conclusion: It was demonstrated that neither HSA-CdTe QDs nor CdTe QDs exhibit genotoxic effects at the embryonic stage. In contrast to CdTe QDs, the bionanocomplex does not cause reproductive toxicity, has significantly lower teratogenic effect, and a toxic impact on the post-embryonic developmental stages. These advantages suggest that HSA-CdTe QDs can be regarded as a relatively safe and promising tool for fluorescence bioimaging *in vitro* and *in vivo* applications in model organisms. However, their use *in vivo* in humans is not recommended.
KEY WORDS: HSA-CdTe QDs; bionanocomplex; CdTe QDs; *Drosophila melanogaster;* toxicity; genotoxicity; fluorescent bioimaging.

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Cadmium telluride (CdTe) semiconductor quantum dots (QDs) are recognized for their unique electronic and optical properties as well as their small size (2–8 nm). They exhibit prolonged and intense fluorescence, excellent photostability, resistance to photobleaching, and suitability for biofunctionalization [1]. These characteristics lead to their widespread application in biological and biomedical research, diagnostics [2, 3] and chemical sensing [4]. Specifically, CdTe QDs have been successfully applied for fluorescence imaging of biological objects [5], targeted tumor imaging [6], long-term bioimaging of cellular processes, biosensing, multiplexed imaging [7] and detection [8], preventive oncology [9]. As nanoparticles, CdTe QDs readily penetrate cells, their nuclei and accumulate within them. They can bind to cellular macromolecules such as proteins and nucleic acids and modify their functions leading to cytotoxic and genotoxic effects at the subcellular, cellular and organismal levels [10, 11]. Specifically, in BALB/c mouse models CdTe QDs induced toxicity and apoptosis of liver cells, spleen damage, and systemic effects [12]. They are also cytotoxic towards mouse endothelial cells, erythrocytes, human and rat T- and B-lymphocytes as well as human colon cancer cells (*Colo* 205) and breast cancer cells (MCF-7) [11]. Furthermore, CdTe QDs induce cellular and organismal toxicity in *D. melanogaster* significantly affecting its survival, development and reproduction [10]. Researchers explain the toxic effects of CdTe QDs to the ability of cadmium ions to slowly release from the complex after entering cells, which initiates the formation of reactive oxygen species (ROS). ROS, in turn, trigger a cascade of biochemical and cellular processes, leading to significant morpho-functional changes and, often, to the death of cells and the entire organism [12, 10]. Given these concerns, research actively continues on developing alternative synthesis methods for CdTe QDs, improving their biocompatibility, and reducing their toxicity by coating them with inert shells or conjugating them with biocompatible polymers [1, 3, 11]. Among promising approaches to reduce CdTe QD toxicity, the preparation of their complex with human serum albumin (HSA) stands out as a biocompatible polymer and protective agent. The literature reports data on the physicochemical and optical properties of the HSA-CdTe biocomplex [13, 14], as well as on the binding strength of CdTe quantum dots to albumin, which depends on the stabilizer used [15]. Human serum albumin forms a protein corona around CdTe quantum dots without altering the protein's native structure, which indicates the biocompatibility of the complex, while slowing complex degradation, limiting Cd^{2+} ion release, and reducing toxicity through decreased levels of reactive oxygen species [15–19]. So, a study [16] demonstrated low toxicity, as well as high stability and prolonged fluorescence, when using this bionanocomplex as a probe for osteosarcoma cell bioimaging. In another study [20] biogenic HSA-CdTe QDs have shown antibacterial activity against both Gram-negative strains (*E. coli*) and Gram-positive strains (*E. faecalis*), as well as pronounced cytotoxic effects against human HeLa cells. Therefore, the aim of our study is to determine the genotoxic potential of the HSA-CdTe QDs bionanocomplex as a potentially safe tool for fluorescence bioimaging, using *D. melanogaster* as a model system. The research also focused on the capability CdTe QDs and HSA-CdTe QDs to penetrate into germline cells and their transmission across subsequent developmental stages.

MATERIALS AND METHODS

Preparation of CdTe quantum dots

Nanoparticles of CdTe were obtained in aqueous solution at room temperature following the procedure described in [13, 21]. As a result, a colloidal solution of CdTe QDs at a concentrationof $1.5 \cdot 10^{-6}$ mol·L^{-1} was obtained and stored in a vacuum desiccator at room temperature and in the dark.

Preparation of HSA–CdTe QDs bionanocomplex

A colloidal solution of CdTe QDs in defined amount was mixed with a prepared solution of $3.0 \cdot 10^{-3}$ mol·L^{-1} human serum albumin (HSA, PJSC Biofarma, Ukraine) in a 1:1 ratio and stirred for 2 min using the LD-265U ultrasonic unit. The experiments were started 10 minutes after mixing. The obtained HSA-CdTe QDs bionanocomplex was used immediately.

Fly strain and maintenance

Laboratory low-mutagenic strain *Oregon R* (wild-type) of *D. melanogaster* [19] was used in our research. The flies and larvae were cultured on a standard *Drosophila* nutrient medium consisting of semolina, sugar, yeast, agar and maintained under standard conditions (at the temperature 25^0C$\pm1^0$C, in dark) [23]. In all experiments an equivalent volume of 5 % glucose was used as control. During the all experiments, the flies were maintained in the dark.

Toxicity analysis of QDs

For the assay, 1-2-day-old flies (50 males and 50 females (10 imagos per tube) *D. melanogaster* were transferred to the test tubes containing filter paper discs saturated with diluted colloidal solutions of CdTe QDs (treatment group-1) or HSA-CdTe QDs (treatment group-2). Stock solutions of QDs were diluted with 5 % glucose at a volumetric ratio of 2:1000 (for CdTe QDs) and 4:1000 (for HSA-CdTe QDs). Solutions were re-applied drop wise as the discs dried. Test tubes containing flies were kept for 3 days under standard conditions. The percentage of surviving flies ($PS_{\%}$), was calculated as a ratio of the number of individuals in experimental group to the number of individuals in the control group [24].

Treatment of *D. melanogaster* with CdTe QDs and HSA–CdTe QDs colloidal solutions

For toxicity assessment in larvae, the tested QDs samples were added to 40 ml of fresh, cooled standard nutrient medium in volumes of 0.08 ml (for CdTe QDs) or 0.16 ml (for HSA-CdTe QDs) for larval feeding. Thus, the concentration of quantum dots in the nutrient medium was $3 \cdot 10^{-9}$ mol/L.

Fly emergence assay and phenotypic analysis of offspring *D. melanogaster*

For the assay, 80 1-2-day-old flies (40 males and 40 females / group) were transferred to each tube (5 males and 5 females / tube) containing standard food (control) and with CdTe QDs (treatment group-1) or HSA-CdTe QDs (treatment group-2) in medium. The tubes were stored under standard conditions throughout the experiment. The parental flies were removed on the third day. The emerged flies in each group were counted. The percentage of fly emergence ($FE_{\%}$) was calculated as the ratio of the number of imagos in experimental group to the number of imagos in control. All of offspring were analyzed for phenotypic defects using a stereomicroscope (Sigeta, China). Flies displaying phenotypic alterations were isolated into separate tube containing standard medium and crossed with normal *Oregon R* imagos. It was done to assess the inheritance and expression of abnormal trait in their offspring.

Genotoxicity assessment

The genotoxicity (mutagenic potential) of CdTe QDs and CdTe QDs-HSA was determined in Dominant Lethal Mutations (DLM) test [22]. Briefly, for DLM test, virgin 1-2-day-old imagos were treated for 3 days with solutions of CdTe QDs or HSA-CdTe QDs dropped on filter paper discs. In experimental variant 1 (typical), only males were treated and then crossed with untreated virgin females. In experimental variant 2 (modified), both males

and females were treated and then crossed with each other.

The frequency of dominant lethal mutations (DLM, %) was calculated as a ratio of the total number of eggs with embryonic death to the total number of fertilized eggs [25].

Fluorescence microscopic analysis of histological preparations

Squash preparations of eggs and larvae obtained in two experimental variants as in DLM test were prepared. Additionally, histological sections of imagos' muscles were prepared as described in the paper [26]. All samples were analyzed with an AxioImager A1 fluorescence microscope (Carl Zeiss MicroImaging, Jena, Germany) and Axio CamMRm digital camera (Carl Zeiss MicroImaging).

Statistical analysis

Statistical significance of the obtained data from control and treated groups was determined using one-way ANOVA with multiple post-hoc comparisons with Tukey (Tukey's Honestly Significant Difference) test. The samples were checked in terms of belonging to normally distributed general populations according to Shapiro-Wilk's test. The Dunnett's multiple comparison test was used to determine the significance of data obtained from the fly emergence assay. The χ^2 test was used to compare the frequencies of phenotypic changes in the offspring. The results were presented as M±SE (mean ± standard error of the mean value), n — number of experiments. Differences between the respective control and the experiment were considered statistically significant (ss) at $p \leq 0.05$, and p values represented as non-significant (ns) when $p > 0.05$.

RESULTS AND DISCUSSION

A colloidal solution of CdTe QDs at a concentration $1.5 \cdot 10^{-6}$ mol·L^{-1} and their bionanocomplex with HSA (hereafter, HSA-CdTe QDs) were used for these studies. We analyzed CdTe QDs and HSA–CdTe QDs for toxicity and genotoxicity in adult *D. melanogaster* and their offspring. We also assessed their ability to penetrate germline cells, eggs, and larvae and transmitting to imago.

Toxicity test of CdTe QDs and HSA-CdTe QDs on the *Drosophila* model

The toxicity test of the colloidal solutions of CdTe QDs and HSA-CdTe QDs toward *D. melanogaster* imagos (males and females) showed 100% fly survival in both treated groups regardless of sex. During the 3-day exposure period all treated flies (with both CdTe QDs and HSA-CdTe QDs) were actively moving, feeding and mating. The obtained results are consistent with the data described in the article [10].

Fly emergence assay

According to Table 1, only Group 1, treated with CdTe QDs, exhibited reduced fly emergence (53%) compared with the control. This reduction was statistically significant ($p < 0.001$) according to Dunnett's test. Group 2 (treated with HSA-CdTe QDs) exhibited a fly emergence rate to 96% compared to the control, which was not statistically significant ($p > 0.05$). Thus, following larval feeding, the HSA-CdTe QDs did not demonstrate toxic effects on the development of *D. melanogaster*, unlike CdTe QDs. A highly significant difference ($p < 0.001$) in fly emergence frequency was detected when comparing Group-1 and Group 2 (Tab. 1). Presumably, the addition of HSA in the colloidal solution CdTe QDs inhibits the spontaneous release of cadmium ions from HSA-CdTe QDs. This likely results in a substantial reduction of its embryotoxic impact, thus exhibiting a protective effect.

Table 1. Fly emergence of offspring *Drosophila melanogaster Oregon R* strain treated with CdTe QDs and HSA-CdTe QDs and their phenotypic analysis

Indicators	Control	group-1 (treatment with CdTe QDs)	group-2 (treatment with HSA-CdTe QDs)
Number of flies per tube, (M±SD)	390±17	206±9	375±14
Total number of flies	1562	823	1500
Percentage of fly emergence ($FE_{\%}$)	100	53	96
p-values*			
Control	-	<0.001	>0.05
Group-1	<0.001	-	<0.001
Group-2	>0.05	<0.001	-
*Significance is ascribed as, $^{ns}p>0.05$ and $^{ss}p<0.001$.			

Table 2. Phenotypic analysis of offspring *Drosophila melanogaster Oregon R* strain treated with CdTe QDs and HSA-CdTe QDs

Abnormal phenotype	**Number of imagos**		
	Control	group-1 (treatment with CdTe QDs)	group-2 (treatment with HSA-CdTe QDs)
Abdominal pigmentaion change	0	3	2
Wing deformities abnormalities	0	6	5
Disrupted body segmentation	0	4	1
Appearance of neoplasms	0	2	2
Imago in cocoon	0	1	
Growth on the head	0		1
Acephaly	0		2
Total	0	16	13
Percentage of fly phenotypic changes ($PC_{\%}$)	0	1,94	0,87
p-values**			
Control	-	<0.001	<0.001
Group-1	<0.001	-	<0.05
Group-2	<0.001	<0.05	-
**χ2-test was used for statistical significance			

Phenotypic analysis of offspring

The phenotypic analysis of progeny treated with CdTe QDs and HSA-CdTe QDs revealed imagos exhibiting diverse phenotypic alterations (Table 2, fig. 1). Specifically,

among 823 progeny from Group1 (Table 1, treatment with CdTe QDs), 16 imagos were found with phenotypic changes, accounting for a frequency of 1.94 %. Most abnormalities were related to wing deformities, similar to those described in the article [10]. Meanwhile, scattered individuals were observed with changes in abdominal pigmentation, body segmentation, neoplasms, and other morphological changes. In group 2 (treatment with HSA-CdTe QDs), 13 out of 1500 offspring (0.87 %) also displayed similar abnormalities. However, no such phenotypic changes were detected in the 1562 offspring analyzed from the control group. A χ^2 test indicated a highly statistically significant difference in the frequencies of phenotypic abnormalities when comparing Group-1 and Group-2 to the control ($\chi^2(2)=27.99$, $p<0.001$). Moreover, a comparative analysis highlighted a statistically significant difference in the incident of phenotypic abnormalities between two studied groups ($p<0.05$). This suggests that HSA-CdTe QDs bionanocomplex is less toxic to *D. melanogaster* development than CdTe QDs, highlighting its diminished adverse effects. Notably, HSA-CdTe QDs induced phenotypic abnormalities at a frequency 2.3 times lower than that caused by CdTe QDs. Flies exhibiting abnormalities (from both groups) were analyzed for their survivability and fertility. Each one was transferred into individual tube (without QDs) and crossed with untreated wild-type imago of *Oregon R* strain. According to our observations, flies showing marked phenotypic changes were not viable: they died and failed to produce offspring. Conversely, individuals with slight abnormalities (mainly deformed wings) remained fertile and yielded phenotypically normal progeny. Clearly, offspring do not inherit or exhibit the phenotypic abnormalities induced in the parental generation by either CdTe QDs or HSA-CdTe QDs. This suggests that the studied quantum dots primarily exert a modifying effect on the morphogenetic processes in flies.

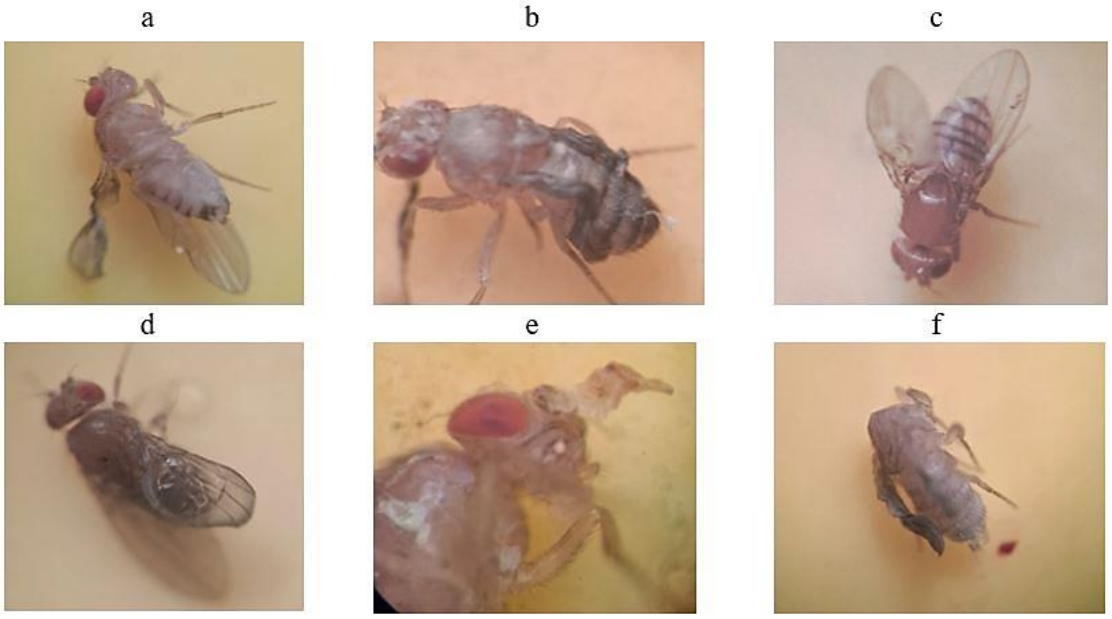

Figure 1. Phenotypic abnormalities in *D. melanogaster* offspring after exposure to CdTe QDs and HSA-CdTe QDs. Images captured using a stereomicroscope: a, b — deformed wings (×112, ×**196**); c — altered wing length (×112); d — malformed wing with a neoplasm (×112); e — growth on the head (×**392**); f — acephaly and deformed wings (×112).

Therefore, the studied HSA-CdTe QDs, similar to CdTe QDs, exerts teratogenic effect in *D. melanogaster*, becoming apparent during the critical period of ontogenesis — organogenesis. Evidently, at the pupal stage, the cells of imaginal discs are highly susceptible to the influence of the tested quantum dots due to their high mitotic and metabolic activities.

Evaluation of the genotoxic potential of CdTe QDs and HSA-CdTe QDs in the dominant lethal mutation test

To evaluate the genotoxic potential of CdTe QDs and HSA-CdTe QDs, the DLM test was employed. This method is effective in detecting considerable chromosomal mutations caused by various xenobiotics, leading to an arrest in development at the early (embryonic) stages [19]. Our data (Fig. 2) indicate that overall DLM% frequency for the CdTe QD-treated groups (3.083 ± 0.073 and 3.089 ± 0.073, respectively) did not significant vary from that of the control group (2.96 ± 0.076). The DLM% frequency for the HSA-CdTe QD-treated groups (2.75 ± 0.07 and 2.853 ± 0.068, respectively) also did not significantly vary from those of the control group (2.96 ± 0.076). The ANOVA test indicated that the observed differences among the mean values of all groups was not substantial enough to be statistically significant ($p=0.453$; $F=0.879$). A pairwise comparison of the DLM% frequency among all investigated groups, conducted using Tukey's test (at $\alpha=0.05$), demonstrated no statistically significant difference ($p>0.05$). Thus, regardless of which parental form consumed the studied QDs — the male (in the typical DLM test variant) or both parents (in the modified variant) there was not statistically significant impact on the elevation of the DLM frequency. Based on these findings, we propose that neither HSA-CdTe QDs nor CdTe QDs exhibit genotoxic effects at the submolecular level in the *D. melanogaster* model.

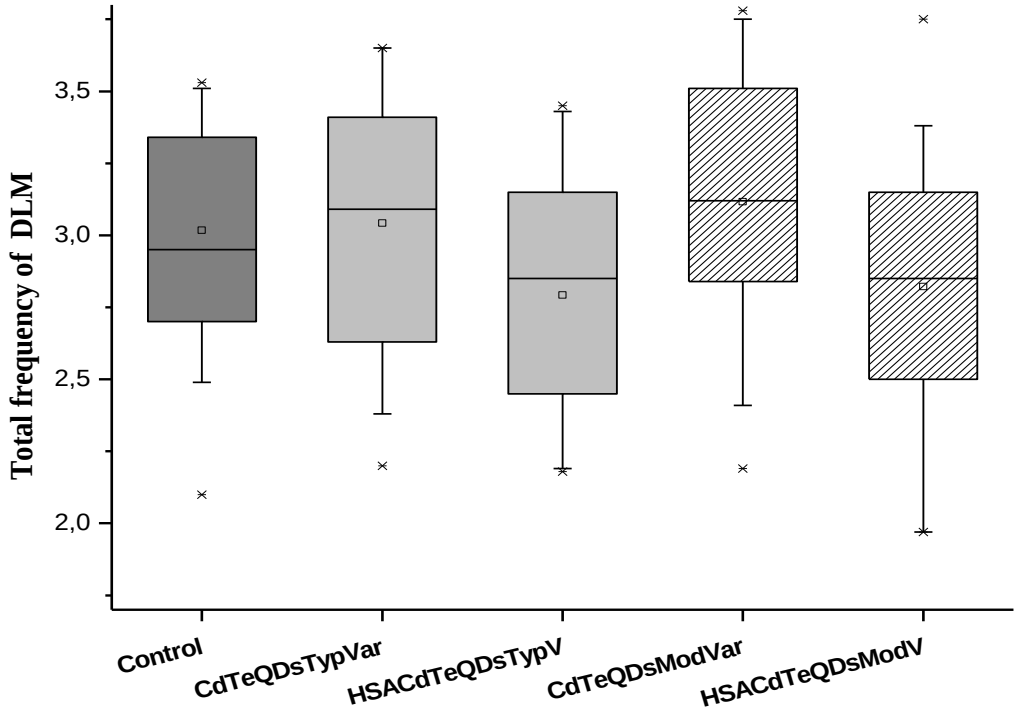

Figure 2. The total frequency of dominant lethal mutations (DLM) *Drosophila melanogaster Oregon R* strain under the influence of CdTe QDs and HSA-CdTe QDs in different experimental variants of test: Control, TypVar — typical variant; ModVar — modifcal variant.

It is important to note that the number of laid and fertilized eggs was significantly reduced in the CdTe QDs-treated group ($p<0.05$), by 24 % and 15 % respectively, compared to the control. The findings suggest that CdTe QDs have a reproductively toxic effect on both females and males. However, in the case of the bioconjugate-treated group, no statistically significant difference ($p>0.05$) was detected in the number of laid and fertilized eggs compared to control group.

Fluorescence visualization of the intergenerational and inter-stage transmission of CdTe QDs and HSA-CdTe QDs in *Drosophila*

To confirm this assumption, we examined the ability of these QDs to penetrate germline cells, eggs, and be transmitted to later developmental stages. For this purpose, two experimental variants were performed. The first experimental variant involved analyzing preparations of unfertilized eggs from treated females. For the second variant, we analyzed preparations of fertilized eggs and larvae obtained by crossing untreated females with treated males. Fig. 3 demonstrates the cellular mass of homogenized eggs, larvae and imagos' muscles, respectively, showing distributed fluorescence in all but control samples.

Our data indicate that both CdTe QDs and the HSA-CdTe QDs penetrate into germ cells of males and females when ingested with food (Fig. 3). During fertilization, these QDs transfer into eggs, and subsequently to larval cells as confirmed by their fluorescence.

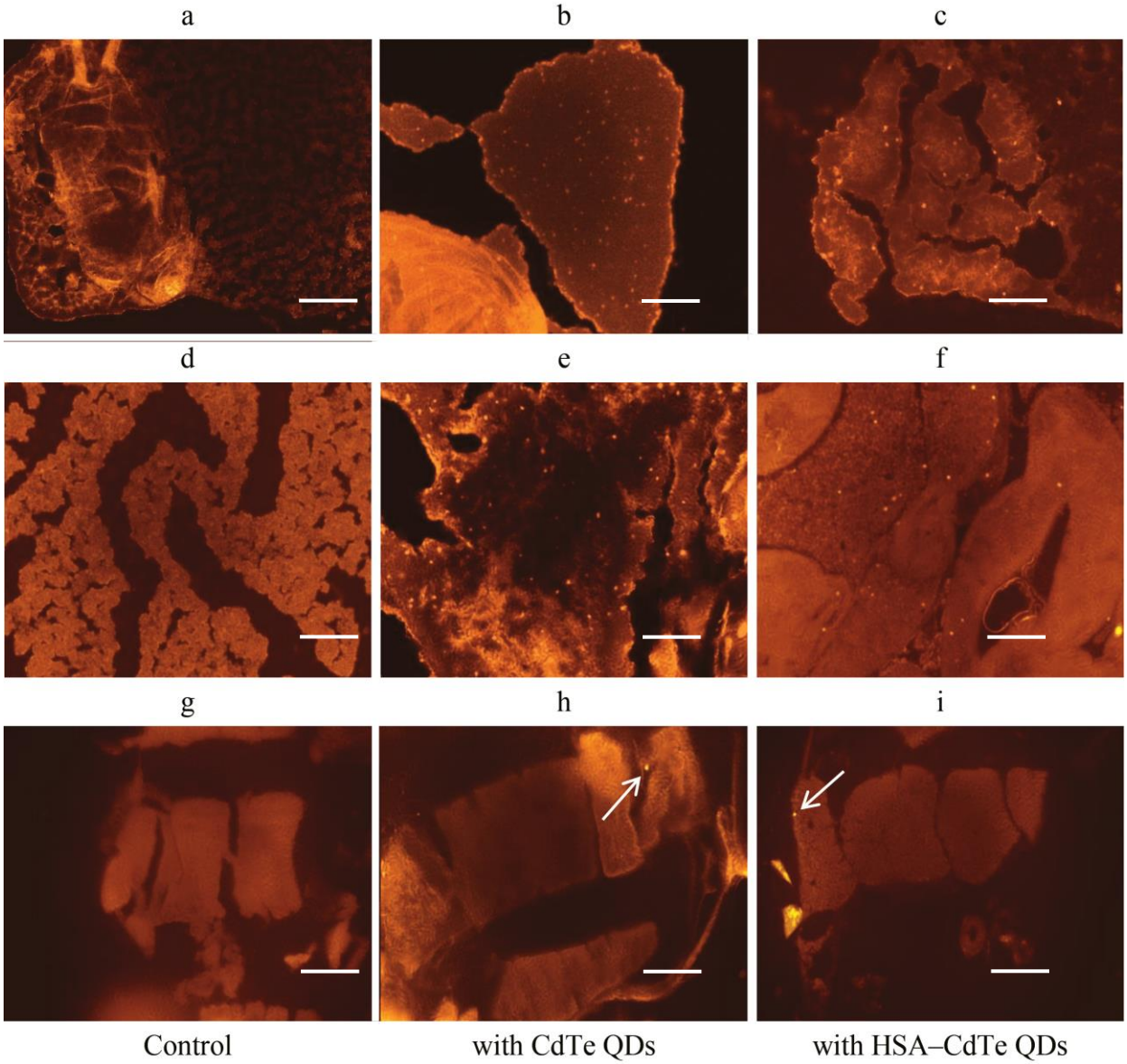

Figure 3. Homogenized eggs (a, b, c), larvae (d, e, f) and histological sections of imagos' muscles (g, h, i) of *D. melanogaster*, untreated (control) and treated with CdTe QDs and HSA-CdTe QDs. Fluorescence imaging was performed using a TRITC filter (emission 570-580 nm, well-suited for visualization of dyes in the orange-red region of the spectrum), with an exposure time of 50 ms at 400× magnification. The segment in the photos corresponds to 50 μm. Arrows indicate CdTe QDs (h) and HSA-CdTe QDs (i).

It was observed that intact eggs do not fluoresce, indicating that the eggshell masks the signal. Therefore, to effectively detect QDs in eggs, it is advisable to prepare crushed slides of the samples. The images on Fig. 3 (h, i) also demonstrate that both types of QDs are present in imagos' muscles in trace amounts. The ability of the bionanocomplexes and QDs to remain in the organism even after metamorphosis highlights their stability and potential for transmission across developmental stages and generations. Thus, the HSA-CdTe QDs bionanocomplexes can be used in biological and biomedical research as a safer tool for bioimaging *in vitro* and *in vivo* applications in model organisms compared to CdTe QDs; however, their use *in vivo* in humans is not recommended.

CONCLUSION

Using fluorescence microscopy, we established that both HSA-CdTe QDs and CdTe QDs were able to penetrate germline cells of the model organism *Drosophila melanogaster*, were transmitted to the progeny, and accumulated particularly in larval and adult muscle tissues, where they were clearly detected in histological sections. This confirmed not only the effective cellular uptake of both types of quantum dots (QDs), but also their stability and persistence during development. Importantly, the Dominant Lethal Mutation test demonstrated that neither HSA-CdTe QDs nor CdTe QDs induced genotoxic effects at the embryonic stage, suggesting that their direct interaction with the genome did not cause heritable chromosomal mutations at early development. This aspect is essential, as it indicates that the observed biological effects are not related to DNA damage, but rather to other mechanisms, likely involving interference with cellular differentiation and developmental processes.

At the same time, feeding experiments revealed that both types of QDs exhibited a teratogenic effect during larval development, leading to phenotypic abnormalities in the offspring of *D. melanogaster*. The presence of such morphological changes indicates that despite the absence of direct genotoxicity, the QDs are capable of disrupting normal ontogenesis, most probably by affecting cell signaling, oxidative stress responses, or tissue-specific development. However, the comparative analysis clearly showed that conjugation of CdTe QDs with human serum albumin (HSA) significantly reduced their teratogenic potential. Specifically, the frequency of phenotypic abnormalities in the case of HSA-CdTe QDs was 2.3-fold lower ($p<0.05$) compared to CdTe QDs, indicating that the albumin coating provides an additional protective effect by decreasing the overall toxicity of the nanoparticles.

Another important observation was that HSA-CdTe QDs did not reduce the number of eclosed offspring in comparison to the control, while CdTe QDs led to a noticeable decline in viability. This suggests that the bioconjugation with HSA not only reduces morphological abnormalities but also helps maintain normal survival rate and reproductive outcomes. The protective effect of HSA likely stems from its ability to improve biocompatibility, reduce surface reactivity, and limit the release of toxic cadmium ions, thereby minimizing negative biological consequences potentially mediated by a decrease in the generation of reactive oxygen species.

In summary, our results highlight the dual nature of CdTe QDs: while they are powerful fluorescent probes with strong visualization capacity, their biological application is limited by their inherent developmental toxicity. Conjugation with HSA substantially mitigates these risks, resulting in improved safety without compromising imaging potential. Thus, HSA-CdTe QDs can be considered a promising and relatively safe nanobiotechnological tool for *in vitro* fluorescence bioimaging, offering an advantageous balance between effectiveness and biosafety. For *in vivo* studies this complex can be used in model organisms, but it is not recommended for human use.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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БІОНАНОКОМПЛЕКС КВАНТОВИХ ТОЧОК CdTe-АЛЬБУМІН: ГЕНОТОКСИЧНИЙ ПОТЕНЦІАЛ ТА ЗАСТОСУВАННЯ ДЛЯ БІОВІЗУАЛІЗАЦІЇ НА МОДЕЛІ *DROSOPHILA MELANOGASTER*

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Актуальність. Дослідження напівпровідникових нанокристалів, відомих як квантові точки (КТ), та їх застосування в біомедичних дослідженнях, біовізуалізації, діагностиці стрімко розвиваються. Хоча КТ демонструють чудові оптичні властивості, їх практичне застосування обмежується токсичністю. У зв'язку з цим тривають дослідження, спрямовані на зниження токсичності КТ шляхом покриття інертними оболонками чи комплексоутворенням з біомолекулами.

Мета роботи: на *D. melanogaster* як моделі оцінити генотоксичний потенціал біонанокомплексу КТ CdTe з альбуміном людини (HSA) як безпечного та перспективного інструменту для флуоресцентної біовізуалізації *in vivo*.

Матеріали і методи. КТ CdTe були отримані хімічним колоїдним методом у водній фазі та кон'юговані з HSA для отримання біонанокомплексу КТ HSA-CdTe. Токсичність і генотоксичність КТ оцінювали у відповідних тестах на моделі *D. melanogaster* (лінія *Oregon R*). Візуалізували КТ флуоресцентною мікроскопією. Отримані дані аналізували статистичними методами, вважаючи відмінності значущими при $p<0,05$.

Результати. Встановлено, що біонанокомплекси, так само як і CdTe КТ, проникали у клітини зародкової лінії модельного організму, переносилися у яйця й личинки та чітко візуалізувалися на гістологічних препаратах. У м'язах імаго виявлялися поодинокі CdTe КТ і кон'югати з HSA. Досліджувані типи КТ не викликали токсичності у імаго за 3-добової експозиції й зниження їх репродуктивної здатності, а також генотоксичного ефекту на ембріональній стадії розвитку у ДЛМ-тесті. При личинковому згодовуванні, обидва типи КТ спричиняли тератогенний ефект. На відміну від CdTe КТ, біонанокомплекс індукував фенотипові аномалії у імаго зі значно меншою частотою (у 2,3 рази) та не спричиняв зменшення їх вильоту порівняно з контролем ($p>0,05$).

Висновки. Показано, що КТ HSA-CdTe та CdTe не виявляють генотоксичної дії на ембріональній стадії розвитку. На відміну від КТ CdTe, біонанокомплекс не чинить репродуктивної токсичності, має значно меншу тератогенну дію й токсичний вплив на постембріональний розвиток моделі. Ці переваги уможливлюють розглядати КТ HSA-CdTe як відносно безпечний та перспективний інструмент для флуоресцентної біовізуалізації *in vitro* та для використання *in vivo* на модельних об'єктах. Однак їхнє застосування *in vivo* у людини не рекомендується.

КЛЮЧОВІ СЛОВА: КТ HSA–CdTe QDs; біонанокомплекс; CdTe QDs; *Drosophila melanogaster;* токсичність; генотоксичність; флуоресцентна біовізуалізація.