Entomotoxicity of TiO$_2$ and ZnO Nanoparticles Against Adults Tribolium Castaneum (Herbest) (Coleoptera: Tenebrionidae)

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Abstract

The red flour beetle *Tribolium castaneum* is one of the common pests of stored grains distributed worldwide. In this study, testing the effect of TiO$_2$ and ZnO nanoparticles as insecticides on adults of *T. castaneum* was achieved. Results showed that the high concentration of TiO$_2$ and ZnO nanoparticles recorded high cumulative mortality of the adult insects after exposure time 1, 3, and 5 days from treatments 15.30, 23.57, and 29.85% respectively of TiO$_2$ nanoparticles compared with 20.42, 27.08, and 33.96 % respectively of ZnO nanoparticles. The result showed that TiO$_2$ and ZnO nanoparticles are effective in controlling and can be introduced in the future in integrated pest management of *T. castaneum*.

Keywords: *Tribolium castaneum*, TiO$_2$ nanoparticles, ZnO nanoparticles.

1.Introduction

The red flour beetle (*Tribolium castaneum* Herbst. 1797) (Coleoptera: Tenebrionidae), is one of the secondary pests of stored grains, causing significant damage at the global level for those stored grains varied between the presence of disagreeable odors secreted by the adults of the insect to the presence of excrement and insect fragments reduce the quality of food products and market value [1]. Recently, as a result of the contamination of stored grains with residual insecticides and fumigants and the growing problem of insect resistance to these chemical pesticides, Researchers turned to safe and environmentally friendly alternatives such as plant extracts, insect pathogens, and using nanoparticles in controlling pests to replacing conventional chemicals [2]. Because of the properties of nanoparticles, which depend on their small size and cover a large surface and then use it in lower quantities and doses. Several studies have indicated the potential of some nanomaterials as insecticides, such as titanium dioxide and zinc oxide [3-6]. Our study aimed to assess the toxicity of TiO$_2$ and ZnO nanoparticles as insecticidal against *T. castaneum* under laboratory conditions.

2.Materials and Methods

The study was conducted at the College of Agriculture, Al Qasim Green University, Babylon, Iraq.

2.1. Insect Collection and Rearing

The Larvae and adults of red flour beetle, *T. castaneum* were obtained from the Insect Laboratory, Plant protection Department, College of the Agriculture University of Kufa - Iraq. The culture of the insect was reared under laboratory conditions in glass jars (1000 mL) comprising of crushed wheat and dry yeast and kept in an incubator at 30±0.5°C with 70 ±% relative humidity and 8 hours dark for several generations. The insect's culture was established to supply an adequate number of insects of similar age for the next experiments.

2.2. Nanoparticles

The TiO$_2$ and ZnO nanoparticles were obtained from Dr Ayad F. Alkaim, Department of Chemistry, College of Science for Women, University of Babylon, Iraq. The particle size of (≤ 100 nm) and was prepared according to the method described by [7].
2.3. **Scanning Electron Microscope (SEM)**

The examination, size, and photographing of the TiO$_2$ and ZnO nanoparticles were measured using a Scanning Electron Microscope at the college of Science, University of Kufa, Najaf, Iraq.

2.4. **Bioassay Test**

Different concentrations of TiO$_2$ and ZnO nanoparticles were admixed with crushed grains to determine their effects on *T. castaneum* by contact toxicity assay at three concentrations 0.5, 1, and 2 gm. /kg. of TiO$_2$ and ZnO nanoparticles, that were prepared and each concentration was added to 10 gm crushed grains in 1000 mL glass jar. The glass jars were shaken manually approximately 1 min to achieve equal distribution the nanoparticle compounds on crushed grains. The jars were kept for 24 hrs. before adding 20 newly emerged adults (1-2 weeks - old) of *T. castaneum* were introduced into each jar. Then, in jars (250 mL), three replicates were made for each treatment as well as the control treatment, which include just crushed grains. All replicates were kept at 27 ± 1 °C and 65 ± 5 % R.H. for all treatments and control were covered with muslin for sufficient ventilation. Insect mortality was checked as cumulative mortality during successive intervals exposure time 1, 3, and 5 days.

2.5. **Statistical analysis**

The percentage of insect mortality was calculated using the corrected Abbot’s formula [8]. The data were analyzed using variance (ANOVA) analysis by using the software GenStat package 3 (3 rd edition). The significant differences between the treatments were observed. Mean values were significantly separated by using the least significant difference (LSD) test at the 5% level.

3. **Results and Discussion**

3.1. **Structural study of nanoparticles**

The samples morphology, structure, and size of nanoparticle compounds were investigated using Scanning Electron Microscopy (SEM). Figure. 1 indicated that the original morphology of the TiO$_2$ nanoparticles was approximately oval shape while ZnO nanoparticles were approximately rhombohedral in shape. It can be seen that the sample consists entirely of nanoparticles with an average size (< 100 nm).

![Figure 1. SEM micrograph of TiO$_2$ (A) and ZnO (B) NPs.](image)

3.2. **Effect of TiO$_2$ and ZnO nanoparticles on mortality of adult *T. castaneum***

The result in the table (1) showed that all concentrations of TiO$_2$ and ZnO nanoparticles were effective on the adults of *T. castaneum*, and the mortality increased with the increasing concentration of both compounds of nanoparticles. Furthermore, the cumulative mortality increased with increased of exposure time (days). Except day 1 had no significance was shown. In
addition, the results of variance showed that the effect of ZnO NPs on adults of *T. castaneum* was superior compared with TiO$_2$ nanoparticles. The mortality result started with 9.98, 11.54, and 15.30% of concentrations 0.5, 1 and 2 gm of TiO$_2$ nanoparticles respectively in day 1 and then increased to 20.27, 25.62, and 29.85% in day 5 of exposure period. While the percentage of mortality of ZnO NPs treatment was started with 12.92, 16.43, and 20.42% at day 1 then reach to 25.12, 29.63, and 33.96% of 0.5, 1 and 2 gm concentration respectively after day 5 from exposure. Similar observations had already been reported by other authors for different species of insects and/or host plants in addition to different types of NPs. These results of our study are consistent with the results of [9] who indicated that ZnO was had the most effective compared to Al$_2$O$_3$ nanoparticles for controlling of *T. castaneum*. Also, the results from this study agree with [10] who reached that TiO$_2$ nanoparticles were highly effective against *Eurygaster testudinaria* where the mortality rates of adults and nymphs were significantly increased with days after application along with increasing of concentration. Similar reports have been documented by [11] who reported that zinc oxide nanoparticles ZnO NPs and hydrophilic silica nanoparticles SiO$_2$ NPs gave high mortality of *Sitophilus oryzae*, *T. castaneum* and *Callosobruchus maculatus* adult at the high concentration. The difference in the effectiveness of nanoparticles is due to the nanoparticle sizes, coatings, concentrations, times of exposure, and the mechanism of its effect is usually through such as adhering to the surface, enter through the exoskeleton of the insect due to the decrease in membrane permeability. As well as denaturation of enzymes and cause DNA damage [12].

**Table 1.** The percent of cumulative mortality of *T. castaneum* adults treated with TiO$_2$ and ZnO.

| Type NPs | Concentration gm./kg. | Days | Mean Mortality |
|----------|-----------------------|------|----------------|
|          |                       | 0.5  | 9.98           | 16.43 | 20.27 | 15.56 |
| TiO$_2$  |                       | 1    | 11.54          | 21.14 | 25.62 | 19.43 |
|          |                       | 2    | 15.30          | 23.57 | 29.85 | 22.90 |
|          |                       | 0    | 0.00           | 4.44  | 5.55  | 3.33  |
| ZnO      |                       | 0.5  | 12.92          | 19.24 | 25.12 | 19.09 |
|          |                       | 1    | 16.43          | 24.02 | 29.63 | 23.36 |
|          |                       | 2    | 20.42          | 27.08 | 33.96 | 27.15 |
|          |                       | 0    | 0.00           | 7.13  | 13.22 | 6.7   |

L.S.D (P ≤ 0.05) Type NPs 0.27, Con. 0.38, Days 0.33, Interference 0.94

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