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RESEARCH ARTICLE

COMPARATIVE BIOACTIVITY OF SILVER, ALUMINUM OXIDE, AND ZINC OXIDE NANOPARTICLES ON THE HOUSE FLY "*MUSCA DOMESTICA* L. (DIPTERA: MUSCIDAE)"

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ABSTRACT

The aim of the current study was to identify and compare the biological consequences of three nanoparticles (NPs): "silver, aluminum oxide, and zinc oxide" against the house fly "*Musca domestica* L.". The NPs were applied by feeding the early second instar larvae on diets mixed with the selected NPs at varying concentrations (5, 10, 20, 30, 40, and 60 mg/g diet). The consequences demonstrated that all the tested NPs were toxic to *M. domestica* larvae. Silver NPs were the most toxic, induced 100% larval mortalities at 40 mg/g diet and its toxicity index was 100. Median lethal concentration values (LC_{50}) were 20.8, 38.7, and 49.6 mg/g diet for Ag, Al_2O_3, and ZnO NPs, respectively. The tested NPs caused a significant prolongation (P<0.05) in larval and pupal period. The pupation percent and adult emergence decreased significantly (P<0.05) by all NPs as contrasted to the control group. All the tested NPs caused a reduction in the larval and pupal weights. In addition, the fecundity and hatchability decreased significantly (P<0.05) by all the NPs. The sterility increased with all the NPs. In conclusion, silver NPs were more effective than the other NPs against the house fly.

INTRODUCTION

The house fly, *Musca domestica* L. (Diptera: Muscidae), is a significant pest in human life. It is frequently shown in homes, horse stables, and poultry farms. It serves as a mechanical vector for over 100 human and animal diseases, as well as various bacterial, viral, protozoan, and helminthic infections, by transmitting a diverse array of pathogens[1]. Because of its importance as a public health pest, many insecticides have been used in *M. domestica* control. However, house flies have evolved resistance to some insecticides, such as permethrin, delta-methrin, beta-cypermethrin, and propoxur[2].

Nanoparticles (NPs) may be a novel and useful method in the hunt for an ecologically acceptable and effective insecticide. The term "NPs" is frequently used to refer to particles having a size range of (1-100 nm). On the basis of distinctive characteristics including size distribution and shape, NPs exhibit entirely new or better qualities in comparison to the huge particles of bulk materials from which they are made[3]. The NPs were categorized according to their characteristics, shape, and size[3]. Among these classes were fullerenes, metal NPs, polymeric NPs, and ceramic NPs[3]. Due to their nanoscale size and huge surface area,

NPs exhibit unique chemical and physical characteristics. They are ideal for a variety of applications due to their features[4]. Magnetic NPs advantages (such as their tiny size, high reactivity, and high capacity) may become lethal factors when combined with undesirable cellular toxic and damaging consequences[4]. Additionally, NPs can enter organisms *via* inhalation or ingestion and can be transported throughout the body to various tissues and organs, where they can have toxicological impacts[4].

As a pure metal or a compound, AgNPs have been used for a number of therapeutic, pharmacological, and agricultural purposes due to their broad range of bioactivities, including insecticidal and antibacterial properties[3,4]. The biological impacts of biosynthesized AgNPs against *M. domestica* were previously evaluated[5,6]. The larvicidal action of AgNPs was tested against the third instar larvae of *M. domestica* by (dipping and feeding approaches), which induced inhibition of pupation and adult emergence[5,6]. The biological effects of AgNPs and other NPs on insect larvae were also studied by many authors on *Tinea Pellionella*[7], *Chironomus riparius*[8,9], *Tribolium* sp.[10,11], *Bombyx mori*[12,13], and the mosquitoes: *Culex* sp., *Anopheles* sp., and *Aedes* sp.[14-17], *Spodoptera* sp.[18,19], and *Agrotis ipsilon*[20]. In addition, the NPs impacts on fecundity and fertility were studied on *Sitophilus oryzae*[21,22], *Drosophila melanogaster*[23], *Callosobruchus maculatus*[24], and *Heliothis virescens*[25]. Thus, the focus of this research was to examine the efficacy of silver, aluminum oxide, and zinc oxide NPs as insecticides towards house fly larvae using the feeding toxicity approach.

MATERIAL AND METHODS

House flies collection and maintenance

Original colony of *M. domestica* was gathered from Research Institute of Medical Entomology, Dokki, Giza, Egypt. The fly colony was kept in the laboratory at a temperature of 27°C and a relative humidity of 55-60%. Adults were kept in rearing cages. The egg batches were collected from soaked cotton and were transferred to clean plastic cups consisting larval feeding medium (bran, yeast powder, milk powder, and water (20: 1: 2: 20), respectively. Each cup was then tightly covered with a piece of gauze by means of a rubber band. Larvae were checked daily for pupation. Pupae were carefully separated with soft forceps and transferred to small plastic cups to complete development for adult emergence in cages[26].

Source of tested NPs

The AgNPs powder was purchased from Sigma-Aldrich, Germany (Cat no.576832). The AgNPs appeared as spherical structures and aggregates; and their diameters were in accordance with manufacturers declarations (<100 nm). The Al_2O_3NPs and ZnONPs powders were purchased from Nanogate, Egypt. They appeared as spherical-like shapes with average sizes <30 nm.

Laboratory bioassay

All tests were performed in laboratory conditions 27±2°C and 55-60% relative humidity. Different concentrations 5, 10, 20, 30, 40, and 60 mg/g diet of AgNPs, Al_2O_3NPs and ZnONPs were prepared by suspending in water. Although aqueous suspensions of NPs are stable, they frequently aggregate in water. To avoid this, the suspensions were vortexed for 20 minutes prior to combining with 5 g of larval feeding media and swirled for a few minutes in a 100 mL beaker (Borosil)[27].

Larvicidal activity

Larvicidal evaluation was made by allowing early second instar larvae (2 days) to feed on a diet mixed with different concentrations of each compound for 72 hours. Control group was made with diet mixed with water only. Early second instar larvae from the stock culture were separated and divided into four groups (4 replicates) each consisting of 25 larvae. Until pupation, larvae were housed in plastic cups containing larval

media. Daily mortality was recorded, and the median lethal concentration (LC_{50}) value was determined. Sun's toxicity index was used to determine the toxicity of the substances evaluated[28]. Larvae were weighted before application and after three days post-treatment to calculate larval growth rate. All control and treated larvae with varying concentrations were monitored daily until the pupal stage to estimate larval duration.

Latent effect on pupae and adult

To assess the pupation percent and pupal weight, the pupae were recorded and weighed, respectively, and were monitored until adult emergence to measure the pupal duration. The reduction in pupal weight and adult emergence were measured according to Khazanie[29]. The resulting adults were used to reveal the effect of the tested NPs on fecundity. The ovi-position deterrent index was measured[30]. The fertility was recognized. The sterility was measured as previously described[31].

Statistical Analysis

Data were subjected to probit analysis[32,33] to calculate the LC_{50} throughout probit transformations. The statistical analysis was conducted using one-way analysis of variance (ANOVA) using SPSS, ver. 22. (IBM Corp, Endicott, NY, USA). Data were handled as a full randomization design. Multiple comparisons were conducted using the Duncun multiple range test, with a significance level less than 0.05[34]. Data were expressed as means and their standard error.

RESULTS

In the present study, early second instar larvae of *M. domestica* were exposed to different concentrations (5, 10, 20, 30, 40, 60 mg/g diet) of three metal NPs mixed with their food for 72 hours. Exposure to Ag, Al_2O_3, and ZnO NPs increased significantly the mortality of *M. domestica* larvae compared with the non-exposed control group (P<0.05). The 100% larval mortality was obtained at 40 mg/g diet of AgNPs; meanwhile, Al_2O_3 and ZnO NPs induced the highest rate of mortality (88 and 72, respectively) at 60 mg/g diet (Table 1). The LC_{50} values were 20.8, 38.7, and 49.6 mg/g diet for Ag, Al_2O_3, and ZnO NPs, respectively. Additionally, the toxicity index was 100, 53.8, and 41.9 for the same previous compounds, respectively, as shown in Table "1".

Table (1): Effect of the tested nanoparticles (NPs) on larval mortality (%) and toxicity index of *M. domestica* treated as second instar larvae.

Concentration (mg/g diet)	Larval Mortality (%)		
	AgNPs	Al_2O_3NPs	ZnONPs
Control	0	0	0
5	23.0 ± 1.2^{eA}	6.0 ± 0.9^{fB}	4.0 ± 0.4^{fC}
10	30.0 ± 2.1^{dA}	16.0 ± 0.7^{eB}	13.0 ± 0.9^{eC}
20	58.0 ± 1.5^{cA}	31.0 ± 1.7^{dB}	27.0 ± 1.1^{dC}
30	92.0 ± 1.6^{bA}	44.0 ± 2.3^{cB}	34.0 ± 0.7^{cC}
40	100.0 ± 0.0^{aA}	58.0 ± 1.2^{bB}	41.0 ± 1.7^{bC}
60	100.0 ± 0.0^{aA}	88.0 ± 1.1^{aB}	72.0 ± 1.5^{aC}
LC_{50} (mg/g diet)	20.8	38.7	49.6
Toxicity index*	100.0	53.8	41.9

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. There is no significant difference (P>0.05) between any two means for the same attribute, within the same row, having the same superscript capital letter. *Toxicity index = (LC_{50} of the most toxic tested compound/LC_{50} of the tested compound) × 100

In treated larvae, a substantial extension of the larval phase was found. The highest prolongation was 7.75 days with AgNPs at 30 mg/g diet followed by 6.0 and 5.62 days with Al_2O_3 and ZnO NPs, respectively, compared with 4.91 days in control larvae (Table 2). Concerning larval growth rate, a significant decrease in the larval growth rate was recorded with all tested NPs after 72 hours post-treatment. The maximum reduction in the larval growth rate was obtained at 30 mg/g diet of Ag (39.83%) followed by Al_2O_3 and ZnO NPs (11.86 and 10.17%, respectively). At 60 mg/g diet Al_2O_3 and ZnO NPs induced 20.34 and 18.64% reduction in growth rate, respectively (Table 3). Moreover, the pupation was significantly reduced to 8, 65, and 66% with 30 mg/g diet of Ag, Al_2O_3, and ZnO NPs, respectively, compared with 100% in untreated larvae. At 60 mg/g diet the pupation was reduced to 12 and 28% with Al_2O_3 and ZnO NPs, respectively (Table 4).

Table (2): Effect of the tested nanoparticles (NPs) on larval duration (days) of *M. domestica* treated as second instar larvae.

Concentration (mg/g diet)	Larval Duration (Days)		
	AgNPs	Al_2O_3NPs	ZnONPs
Control	4.91 ± 0.04^{dA}	4.91 ± 0.04^{fA}	4.91 ± 0.04^{eA}
5	5.96 ± 0.08^{cA}	5.02 ± 0.06^{fB}	4.98 ± 0.08^{eB}
10	5.99 ± 0.07^{cA}	5.38 ± 0.07^{eB}	5.21 ± 0.10^{dC}
20	6.58 ± 0.18^{bA}	5.80 ± 0.09^{dB}	5.50 ± 0.05^{cC}
30	7.75 ± 0.09^{aA}	6.00 ± 0.11^{cB}	5.62 ± 0.05^{bcC}
40	-	6.20 ± 0.04^{bA}	5.80 ± 0.04^{bB}
60	-	6.70 ± 0.09^{aA}	6.30 ± 0.04^{aB}

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. There is no significant difference (P>0.05) between any two means for the same attribute, within the same row, having the same superscript capital letter.

Table (3): Effect of the tested nanoparticles (NPs) on larval growth rate and reduction in growth rate (%) of *M. domestica* treated as second larval instar.

Concentration (mg/g diet)	AgNPs		Al_2O_3NPs		ZnONPs	
	Growth Rate	Reduction	Growth Rate	Reduction	Growth Rate	Reduction
Control	1.18 ± 0.01^{aA}	-	1.18 ± 0.01^{aA}	-	1.18 ± 0.01^{aA}	-
5	1.12 ± 0.01^{bB}	5.08	1.13 ± 0.02^{bB}	4.24	1.16 ± 0.01^{abA}	1.69
10	1.09 ± 0.03^{bB}	7.63	1.12 ± 0.01^{bA}	5.08	1.14 ± 0.01^{bA}	3.39
20	0.97 ± 0.04^{cB}	17.80	1.08 ± 0.01^{cA}	8.47	1.09 ± 0.02^{cA}	7.63
30	0.71 ± 0.04^{dB}	39.83	1.04 ± 0.01^{dA}	11.86	1.06 ± 0.00^{cA}	10.17
40	-	-	0.99 ± 0.01^{eB}	16.10	1.03 ± 0.00^{dA}	12.71
60	-	-	0.94 ± 0.00^{fA}	20.34	0.96 ± 0.01^{eA}	18.64

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. There is no significant difference (P>0.05) between any two means for the same attribute, within the same row, having the same superscript capital letter.

Table (4): Effect of the tested nanoparticles (NPs) on pupation (%) of *M. domestica* treated as second instar larvae.

Concentration (mg/g diet)	Pupation (%)		
	AgNPs	Al_2O_3NPs	ZnONPs
Control	100.00 ± 0.00^{aA}	100.00 ± 0.00^{aA}	100.00 ± 0.00^{aA}
5	77.00 ± 0.63^{bC}	94.00 ± 0.55^{bB}	96.00 ± 0.41^{aA}
10	70.00 ± 0.55^{cC}	84.00 ± 0.44^{cB}	87.00 ± 0.48^{bA}
20	42.00 ± 0.69^{dC}	96.00 ± 0.48^{dB}	73.00 ± 0.46^{cA}
30	8.00 ± 0.41^{eC}	65.00 ± 0.43^{eB}	66.00 ± 0.29^{dA}
40	-	42.00 ± 0.65^{fB}	59.00 ± 0.45^{eA}
60	-	12.00 ± 0.38^{gB}	28.00 ± 0.35^{fA}

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. There is no significant difference (P>0.05) between any two means for the same attribute, within the same row, having the same superscript capital letter.

Table "5" showed that the pupal duration was also prolonged to 9.23, 8.23, and 7.90 days with Ag, Al_2O_3 and ZnO NPs, respectively, at 20 mg/g diet compared with 7.12 days in control ones. Mean pupal weight decreased significantly; it was 5.28, 9.44, and 9.91 mg with Ag, Al_2O_3, and ZnO NPs, respectively, at 30 mg/g diet. A significant reduction in pupal weight was recorded at 60 mg/g diet of Al_2O_3 and ZnO NPs (8.82 and 9.43 mg, respectively) compared with 11.10 mg/g diet in control pupae. The reduction in pupal weight was 52.43, 14.95, and 10.72% with 30 mg/g diet of Ag, Al_2O_3, and ZnO NPs, respectively. Al_2O_3 and ZnO NPs induced 20.54 and 15.04%, respectively at 60 mg/g diet (Table 6).

Table (5): Effect of the tested nanoparticles (NPs) on pupal duration (days) of *M. domestica* treated as second instar larvae**.**

Concentration (mg/g diet)	Pupal Duration (Days)		
	AgNPs	Al_2O_3NPs	ZnONPs
Control	7.12 ± 0.11^{dA}	7.12 ± 0.11^{gA}	7.12 ± 0.11^{gA}
5	7.42 ± 0.05^{cA}	7.30 ± 0.04^{fB}	7.23 ± 0.05^{fB}
10	8.71 ± 0.07^{bA}	7.70 ± 0.06^{eB}	7.50 ± 0.02^{eC}
20	9.23 ± 0.11^{aA}	8.23 ± 0.05^{dB}	7.90 ± 0.07^{dC}
30	-	8.37 ± 0.03^{cA}	8.01 ± 0.04^{cB}
40	-	8.50 ± 0.01^{bA}	8.23 ± 0.03^{bB}
60	-	8.93 ± 0.07^{aA}	8.42 ± 0.06^{aB}

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. There is no significant difference (P>0.05) between any two means for the same attribute, within the same row, having the same superscript capital letter.

Table (6): Effect of the tested nanoparticles (NPs) on pupal weight (mg) and weight reduction (%) of *M. domestica* treated as second instar larvae.

Concentration (mg/g diet)	AgNPs		Al_2O_3NPs		ZnONPs	
	Weight (mg)	Reduction (%)	Weight (mg)	Reduction (%)	Weight (mg)	Reduction (%)
Control	11.10±0.09^{aA}	-	11.10±0.09^{aA}	-	11.10±0.09^{aA}	-
5	10.30±0.08^{bC}	7.21	10.50±0.04^{bB}	5.41	10.62±0.05^{bA}	4.32
10	9.50±0.11^{cC}	14.41	9.83±0.07^{cB}	11.44	10.25±0.06^{cA}	7.66
20	8.36±0.07^{dC}	24.68	9.57±0.08^{dB}	13.87	10.03±0.12^{dA}	9.64
30	5.28±0.03^{eC}	52.43	9.44±0.06^{eB}	14.95	9.91±0.06^{dA}	10.72
40	-	-	9.24±0.06^{fB}	16.76	9.78±0.05^{eA}	11.89
60	-	-	8.82±0.08^{gB}	20.54	9.43±0.04^{fA}	15.04

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. There is no significant difference (P>0.05) between any two means for the same attribute, within the same row, having the same superscript capital letter.

Taking into consideration the observed data, it is clear that all tested NPs inhibited adult emergence (Table 7). Percentage of reduction in adult emergence was 75.5% at 20 mg/g diet with AgNPs representing the highest inhibition. However, the percentage of adult inhibition was 66.0 and 62.8% with Al_2O_3NPs and ZnONPs, respectively compared with the control group (Table 7). Also, the tested NPs prolonged the post oviposition period; Ag NPs were more effective that other NPs (Table 8). Fecundity of *M. domestica* females resulted from larval exposure to different NPs was represented by eggs numbers laid by female, which had a significant reduction in the treated groups (Table 9). Additionally, oviposition deterrent index reduced significantly in the treated groups contrasted to normal one. Hatch-ability was also disturbed, its percentage was 61.9, 76.0, and 84.2% in Ag, Al_2O_3, and ZnO NPs, respectively, compared with 92.0% in the control group. A significant increase in sterility was obtained in all treated adults reaching 76.1% with AgNPs followed by 49.8% with Al_2O_3NPs and 22% with ZnONPs compared with zero level in the control groups (Table 9).

Table (7): Effect of the tested nanoparticles (NPs) on adult emergence and reduction in adult emergence (%) of *M. domestica* treated as second instar larvae.

Concentration (mg/g diet)	AgNPs		Al_2O_3NPs		ZnONPs	
	Adult Emergence	Reduction	Adult Emergence	Reduction	Adult Emergence	Reduction
Control	94.0±0.4^{aA}	0	94.0±0.4^{aA}	0	94.0±0.4^{aA}	0
5	53.0±0.9^{bC}	43.6	75.0±0.4^{bB}	20.2	81.0±0.4^{bA}	13.8
10	41.0±0.4^{cC}	56.4	62.0±0.5^{cB}	34.0	68.0±0.9^{cA}	27.7
20	23.0±0.4^{dC}	75.5	49.0±0.4^{dB}	47.9	56.0±0.5^{dA}	40.4
30	-	-	46.0±0.4^{eB}	51.1	51.0±0.5^{eA}	45.8
40	-	-	43.0±0.6^{fB}	54.3	47.0±0.6^{fA}	50.0
60	-	-	32.0±0.9^{gB}	66.0	35.0±0.4^{gA}	62.8

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. There is no significant difference (P>0.05) between any two means for the same attribute, within the same row, having the same superscript capital letter.

Table (8): Effect of LC_{50} of the tested nanoparticles (NPs) on oviposition periods and female longevity (days) of *M. domestica* resulted from treatment of second instar larvae.

	Pre-oviposition Period	Oviposition Period	Post-oviposition Period	Longevity (Days)
Control	5.0±0.1[c]	23.0±1.1[a]	5.0±0.6[d]	33.0
AgNPs	6.0±0.1[a]	15.0±0.7[b]	11.0±0.3[a]	32.0
Al_2O_3NPs	5.5±0.1[b]	17.0±0.8[b]	9.0±0.5[b]	31.5
ZnONPs	5.2±0.04[c]	22.0±0.4[a]	7.0±0.4[c]	34.2

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter.

Table (9): Effect of LC_{50} of the tested nanoparticles (NPs) on fecundity, oviposition deterrent index, hatchability, and sterility (%) of *M. domestica* resulted from treatment of second instar larvae.

	Fecundity	*Oviposition Deterrent Index	Hatchability	Sterility
Control	270.0±3.1[a]	-	92.0±3.0[a]	-
AgNPs	96.0±3.5[d]	47.5	61.9±3.1[d]	76.1
Al_2O_3NPs	164.0±3.9[c]	24.4	76.0±1.3[c]	49.8
ZnONPs	230.0±4.6[b]	8.0	84.2±1.1[b]	22.0

There is no significant difference (P>0.05) between any two means within the same column having the same superscript small letter. *Oviposition deterrent index = [(A–B)/(A+B)] ×100 Where: A = number of eggs/female in control, B = number of eggs/ female in treatment[30].

DISCUSSION

The current results revealed that AgNPs had the highest toxicity against *M. domestica* larvae followed by Al_2O_3NPs and ZnONPs. AgNPs toxicity towards *M. domestica* obtained in the current study is in accordance with previous reports on the same insect[5,6]. Similar larval mortality induced by AgNPs against other insect species was reported against *Anopheles subpictus*, *Culex quinquefasciatus*, *Aedes aegypti*, *Anopheles stephensi*, *Aedes aegypti*, and *Aedes albopictus*[14-16]. AgNPs may induce toxicity though multiple mechanisms including surface attachment, membrane properties alteration eventually affecting permeability of cell[35]. AgNPs may alter physical and chemical characteristics as a result of their interaction with bio-chemical and physiological structures and processes[36,37]. Insect mortality could be attributed to the digestive tract dysfunction or surface change of the integument due to dehydration or spiracle and trachea blockage[22]. Larvicidal effect of Al_2O_3NPs used in the current study was reported against *Sitophilus oryzae*[38] and *C. quinqufasciatus*[39]. The resultant toxicity of Al_2O_3NPs was attributed to their attachment to the insect cuticle, accompanied by wax and lipid physicosorption, resulting in insect dehydration[40].

In this work, reduction in larval and pupal weight recorded with the tested NPs was equivalent to that noted against *S. littoralis*[19] and against *B. mori*[12], and attributed the variation of growth in response to NPs medications is based on the size, type of NPs, and insect species. Additionally, in the present study the pupation percent was reduced by NPs in a concentration dependent manner. Similar observation was also noticed using ZnONPs against *S. littoralis*[19] and using AgNPs against *B. mori*[41].

The reduction in adult emergence of *M. domestica* as a consequence of the treatment with the tested NPs was in consistent with previous data on other insect species, as reported against *S. littoralis* using ZnONPs[19]. The decrease in adult longevity (especially oviposition period) of *M. domestica* obtained by the treatment with the tested NPs might be due to their accumulation in the different developmental stages. The efficiency of ZnONPs was also demonstrated against *Spodoptera frugiperda* at various doses (100-500 ppm), and adverse effects on development and the number of days required for the insect to finish its life cycle were reported[42].

The obtained results indicated that the tested NPs affected fecundity and fertility of *M. domestica*. Similar results were stated using AgNPs on *D. melanogaster*[23], *Heliothis* sp., and *Trichoplasia ni*[25], and ZnONPs on *S. oryzae* and *S. zaemais*[21]. It was noted that the higher surface-to-volume ratio of NPs makes them more reactive than their bulk counterpart[43]. The NPs toxicity may be also attributed to partial lysis of midgut epithelial cells and disruption to the epithelial cells' apical membrane[17]. They killed the bug by absorbing into the cuticular lipids and causing physical harm[44]. By penetrating the exoskeleton and entering the intra-cellular region, NPs usually cause damage to the insect[45]. The efficiency of NPs varies depending on their sizes, coatings, concentrations, and exposure period[46].

In conclusion, the current study demonstrated the insecticidal activity of three metal NPs, which produced a wide range of biological adverse impacts against *M. domestica* emphasizing their effective-ness as insecticidal activity.

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CONFLICT OF INTEREST
Authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTIONS
AAA planned the study and designed all experiments; SZM carried out the experiments; SHM performed the statistical analysis and interpreted the results; AAA and SHM wrote the draft, edited, and revised the manuscript. All authors approved the manuscript.

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النشاط البيولوجي المقارن لجسيمات الفضة وأكسيد الألومنيوم وأكسيد الزنك النانوية على الذبابة المنزلية "*Musca domestica* L.".(Diptera:Muscidae)"

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هدفت الدراسة الحالية إلي تحديد ومقارنة النتائج البيولوجية لثلاثة جسيمات نانوية من الفضة وأكسيد الألومنيوم وأكسيد الزنك ضد الذبابة المنزلية "*Musca domestica* L.". تم إعطاء الجسيمات النانوية بتغذية يرقات العمر الثاني المبكر على غذاء مخلوط مع الجسيمات النانوية بتركيزات مختلفة (5، 10، 20، 30، 40، 60 مجم/جرام من الوجبة). أوضحت النتائج أن جميع الجسيمات النانوية المختبرة كانت سامة ليرقات الذبابة المنزلية. وكانت جسيمات الفضة النانونية هي الأكثر سُمية، وتسببت في موت اليرقات بنسبة 100% عند 40 مجم/جرام من الوجبة، وكان مؤشر السُمية يساوي 100. وكانت قيم التركيز نصف المميت "LC_{50}" هي 20.8 و 38.7 و 49.6 مجم/جرام من الوجبة لجسيمات الفضة وأكسيد الألومنيوم وأكسيد الزنك النانونية، على التوالي. تسببت الجسيمات النانوية المختبرة في إطالة ملحوظة إحصائيًا ($P<0.05$) في عمر اليرقات والعذارى. وانخفضت النسبة المئوية للعذارى وظهور الحشرات الكاملة بشكل ملحوظ إحصائيًا ($P<0.05$) على عكس المجموعة الضابطة. وأدت جميع الجسيمات النانوية المختبرة إلى انخفاض في وزن اليرقات والعذارى. بالإضافة إلى ذلك انخفضت الخصوبة وقابلية الفقس بشكل ملحوظ إحصائيًا ($P<0.05$) بالمعاملة بالجسيمات النانونية. كما زاد العقم بالمعاملة بالجسيمات النانوية. والخلاصة: كانت جسيمات الفضة النانوية أكثر فعالية من الجسيمات النانونية الأخرى ضد الذبابة المنزلية.