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Efficiency Evaluation of Silica Nanoparticles as a Pesticide against *Ctenocephalides felis*

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ABSTRACT

The increasing resistance of arthropods to many insecticides has encouraged researchers to search for new alternatives to combat harmful insects. The present study aimed to evaluate the effectiveness of silica nanoparticles (NPs) on *Ctenocephalides felis* (*C. felis*), a prevalent species among cats and a known vector for diseases. The killing efficacy of SiO2-NPs against *C. felis* was tested at three different concentrations (50, 100, and 150 mg/ml) over three different time intervals (10, 20, and 40 minutes), alongside positive and negative control groups (distilled water and cypermethrin). The results of the current study indicated that all concentrations had a fleacidal effect, with SiO2-NPs demonstrating increased efficacy with higher concentrations and longer exposure periods. The concentration of 150 mg/mL of SiO2-NPs led to the highest effect at 96% upon exposure for 40 minutes. The results of the current study revealed significant differences between the control groups and all the groups treated with Sio2-NP concentrations. It can be concluded that Sio2-NPs are a practical approach to flea control although it is necessary to search for environmentally friendly pesticides. The current results indicate that SiO2-NPs have anti-parasitic effects against *C. felis*.

Keywords: Cat fleas, Iraq, Nanoparticles, Pesticide, Silica

INTRODUCTION

Nanotechnology is an important technology recently used against various pathogens, such as bacteria, fungi, and parasites. Recent studies have indicated the possibility of using nanomaterials as effective pesticides against insect pests and plant pathogens (Thabet et al., 2021). Nanopesticides are soluble in water and have no environmental risks, compared to traditional insecticides (Goswami et al., 2010; Abbasi et al., 2020; Croissant et al., 2020).

Silica nanoparticles (NPs) have received great attention as a potential alternative to traditional insecticides due to the direct effects of silica NPs on many pest insects. In addition, other studies investigated the field effects of silica on some insect pests (El-Samahy and Galal, 2012; Mousa et al., 2014; El-Samahy et al., 2015).

Ctenocephalides felis (*C. felis*) are external parasites infecting domesticated cats and dogs (Rust, 2017). It is one of the most common types of fleas, and its spread has increased in recent years due to people's interest in domesticating cats (Paterson, 2008; Rust, 2016). Cat fleas, specifically *C. felis*, play a crucial role in transmitting various diseases, such as plague, murine typhus, and tapeworms, to humans and animals. Moreover, *C. felis* is known as an intermediate host for *Dipylidium caninum* (Rousseau et al., 2022). The salivary secretions of *C. felis* can lead to a severe infection called flea dermatitis (Manvell et al., 2022), and consequently, hyperpigmentation, alopecia, and pyoderma (Noli, 2020). Given the resistance of fleas to insecticides and the role that nanoparticles play in treating many diseases, the current study aimed to examine the effectiveness of silica oxide nanoparticles (SiO2-NPs) on fleas *in vitro*.

MATERIALS AND METHODS

Ethical approval

The current study was approved ethically by the Committee of Department of Biology, Faculty of Education, University of AL-Qadisiyah, Iraq.

Sample collection

An examination was conducted on 51 domestic cats (*Felis catus*) admitted to the General Veterinary Hospital in Diwaniyah, among which 12 cats were infected with fleas. Samples of adult species *C. felis* were collected from the cat's hair using Flea combs from different body areas, including the head, under the tail, and abdomen. The fleas were then

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removed using forceps and placed in plastic boxes. These samples were transported directly to the Parasitology Laboratory in the Department of Life Sciences, College of Education, Al-Qadisiyah University, Iraq.

Preparation of Silica nanoparticles

Silica nanoparticles were acquired in the form of ready-made oxide from an American company (Sky Spring Nanoparticles). The material was presented as a fine white powder composed of Sio2NPs ranging in size from 10 to 30 nm with a purity of 99.5%.

A stock solution of Sio2NPs was prepared by dissolving 3 g of Sio2NPs in a liter of distilled water, and it was sterilized by autoclave. After that, the solution was mixed using an ultrasonic homogenizer for 20 minutes, and then the three concentrations (50, 100, and 150) were prepared and placed in the refrigerator (Haghi et al., 2012).

The anti-flea effect of Silica nanoparticles

To investigate the anti-flea effect of Sio2-NPs, *C. felis* flea samples were collected, and their diagnosis was confirmed using a compound light microscope (Olympus, Japan) at 40× magnification. The fleas were distributed on 15 petri dishes, with 5 fleas placed in each dish. For dishes 1-3, 0.5 ml of distilled water was added as a positive control group. Dishes 4-6 received Cypermethrin 10% (Mainland, China). They were left as a negative control group, while dishes 7 to 15 received three different concentrations of Sio2-NPs at levels of 50 mg/ml, 100 mg/ml, and 150 mg/ml, with three replicates for each concentration. The examination of the dishes was repeated after 2-6 hours to ensure the death of the fleas.

The petri dishes were then examined under a light microscope to observe any expected movement of the fleas after 10, 20, and 40 minutes for each concentration, and the immobile fleas were considered dead (Meinking et al., 1986).

Statistical analysis

A completely randomized design was used in a two-factor experiment (concentrations and time periods) and for three replicates. The results that were obtained were subjected to statistical analysis using SPSS software version 24. Least Significance Differences (LSD) was performed, and the probability level was $p < 0.05$.

RESULTS

The results of testing the effectiveness of Sio2-NPs on *C. felis* at three different concentrations of 50, 100, 150 mg/ml and for three-time intervals of 10, 20, and 40 minutes revealed that all the mentioned concentrations had pesticidal effects to varying degrees (Table 1). It was noted that the effectiveness of Sio2-NPs increased with increasing concentration and duration of exposure to the pesticide. The 150 mg/ml concentration indicated the best pesticide effect of 96% after 40 minutes, which was the highest percentage, compared to other concentrations and time intervals ($p < 0.05$). The lowest mortality rate was recorded for the group treated with a 50 mg/ml concentration, reaching 22.3% at 10 minutes.

After 40 minutes, all concentrations of Sio2-NPs had pesticidal effects, reaching 78%, 79.81, and 96%, respectively. The effectiveness of Sio2NPs began to decrease with decreasing time, as the percentage of *C. felis* deaths in the three concentrations after 20 minutes reached 45%, 74.69%, and 89.91%, respectively. At the same time, the lowest flea mortality rate was recorded for the three concentrations after 10 minutes, with percentages reaching 22.3%, 68%, and 81%, respectively. Statistical analysis showed significant differences between the treatment groups and the control group ($p < 0.05$).

Table 1. Anti-activity of SiO2-NPs against cats' fleas at different time intervals

Concentrations (mg/ml)	10 minutes	20 minutes	40 minutes
50	22.3 ± 0.0	45 ± 4.76	78 ± 4.89
100	68 ± 0.0	74.69 ± 4.62	79.81 ± 4.89
150	81 ± 0.0	89.81 ± 4.89	96 ± 4.76
Cypermethrin 10%	90 ±3.0	92 ± 4.91	99 ± 4.89
Negative control	0	0	0

Time (minutes) / mortality rates of *C. felis* (%)

DISCUSSION

In recent years, concern has increased as a result of the resistance of many arthropods to pesticides, coupled with the persistence of these pesticides in soil, groundwater, and food. This escalating issue necessitates the exploration of novel

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alternatives. Nanoparticles, receiving significant attention in arthropod control, have emerged as a promising avenue to address these challenges (Marimuthu et al., 2010; Norouzi et al., 2022).

The results of the current study indicated that the three concentrations of SiO2-NPs led to the inhibition and paralysis of flea movement and then their death in varying time intervals. It was observed that the flea mortality rate increased with increasing concentration and period of exposure to SiO2-NPs. Observations, conducted by calculating the percentage of deceased *C. felis* at three different time points (10, 20, and 40 minutes) for each concentration revealed a consistent trend. The highest percentage of dead fleas treated with SiO2NPs occurred after 40 minutes, indicating an increased efficacy with prolonged exposure. In contrast, the lowest percentage of dead fleas was noted after 10 minutes of treatment. Notably, these percentages were comparatively lower than those recorded after 20 and 40 minutes of treatment.

The concentration of 150 mg/ml was the most efficient, compared to the two concentrations of 50 mg/ml and 100 mg/ml, as it led to a killing rate of 96% after 40 minutes. Generally, the results of the current study align with those reported by other researchers who have examined the effect of SiO2-NPs on various arthropods. For instance, Norouzi et al. (2022) examined the effects of SiO2-NPs on ticks using different concentrations. Moreover, Thabet et al. (2021) focused on their influence against different insect pests. Both studies, similar to the current research, observed that SiO2-NPs possess the ability to kill or repel pests and predatory insects, whether directly or indirectly. The effects of SiO2-NPs on some insect pests belonging to Lepidoptera were also investigated in the laboratory by Mousa et al. (2014). It was found that Sio2NPs could be used to combat *Mythimna separate.*

In another study, Vani and Brindhaa (2013) found that amorphous Sio2-NPs had an effective toxic effect against the stored grain pest *Corcyra cephalonica*, leading to a 100% kill rate. On the other hand, Sio2NPs are promising insect control materials that have been tested as alternatives to pesticides and chemical compounds (Salem, 2020). In the same context, Biradar et al. (2021) noted the superiority of silica nanoparticles over zinc and copper nanoparticles in eliminating *Corcyra cephalonica*, indicating that an increase in concentration and exposure period led to an increase in the mortality of the insect in its various phases

The high percentage of fleas killed by silica particles is due to several reasons. It is plausible that these particles may erode the insect's skin or be absorbed through the skin layers. Alternatively, Sio2NPs penetrate the insect's outer shell and affect the nervous system of *C. felis*, leading to its death. Silica NPs may have an indirect insecticidal effect by blocking the digestive system and causing deformation of the external morphology (Thabet et al., 2021).

CONCLUSION

It is concluded that nanoparticles can be applied as an effective approach to control flea. Results of the current study indicate that SiO2-NPs have anti-parasitic properties and effects against *Ctenocephalides felis*, particularly at a concentration of 150 mg/ml after 40 minutes of exposure.

DECLARATIONS

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Competing interests

The authors declared that we have no conflict of interest.

Authors' contributions

Sadiya Aziz Anah and Saad Aziz Anah contributed to collecting samples, implementing the experiment, and statistically analyzing data. All authors checked and confirmed the final draft of the manuscript.

Ethical consideration

Ethical issues, such as data fabrication, double publication and submission, redundancy, plagiarism, consent to publish, and misconduct, have been checked by all the authors before publication in this journal.

Availability of data and material

The data of the current study are available by reasonable request from authors.

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