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Research Paper

Prophylactic efficacy of silymarin upon renal dysfunction induced by copper oxide nanoparticle

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ABSTRACT

Background: Copper oxide nanopar ticles (CuO-NPs) are more and more used in biomed ical and environmental uses, so people are getting worried about possible organ toxicity when the exposure happens repeatedly. Renal tissue, seen as a main place where nanoparticles are collected and then removed, is basically the most fragile part.
Objective: This study was done to check the kidney-damaging effects of CuO-NPs on renal dysfunction markers and oxidative stress readouts, and also to look at whether silymarin (SLM) can act as a shield in a rat setup.
Methods: We used twenty-four adult male Wistar rats, they were split randomly into four groups of equal size (n=6): (1) Control (CON) distilled water only; (2) CuO-NPs oral gavage with copper oxide nanoparticles; (3) CuO-NPs + SLM oral co-administration of CuO-NPs together with silymarin; (4) SLM silymarin alone. After finishing the experimental period, the animals were euthanized and then serum samples as well as kidney homogenates were collected for biochemical assessment of renal function indicators, plus oxidative stress parameters.
Results: The rats treated with CuO-NPs, showed clear harmful changes in every renal biomarker measured when compared with controls, which points to strong nephrotoxicity. When SLM was given alongside CuO-NPs, those bad biochemical shifts and oxidative stress alterations were notably reduced, bringing many values back closer to control like readings. The group that received SLM by itself did not show any meaningful difference from control levels.
Conclusion: High-dose CuO-NPs cause noticeable renal functional impairment in rats, which is shown by disruption of key nephrotoxicity markers and oxidative balance. Meanwhile, Silymarin shows a real nephroprotective effect against CuO-NP-induced kidney damage, and it looks like it should be studied more, as a possible therapeutic or prophylactic option during nanoparticle exposure.

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1. INTRODUCTION

Nanomedicine has seen tremendous progress in the twenty-first century, owing to its great contributing role in facilitating the diagnosis and medication of abundant diseases, especially intractable ones [1], [2], [3], [4]. Nanoparticles with extremely small sizes (1-100 nm) have participated in many biomedical applications for their distinctive physicochemical characteristics, especially the high surface area to volume ratio [5], [6].

Research topics related to NPs, especially metal oxides, have garnered a lot of attention due to their frequent use in modern life [7], [8]. Copper oxide nanoparticles (CuO-NPs) are among the notable metal oxide nanoparticles that are frequently consumed in a diversity of technological, industrial, and medical applications, including electronics, catalysts, gas sensors, metallic coatings, herbicides, algaecides, inks, and antimicrobial products [9], [10]. On the contrary, continued exposure to these particles has potentially harmful effects on human and animal health a like [11]. As these particles have a high ability to enter the circulatory system, penetrate physiological barriers, and reach most vital organs [12]. Notably, in vivo studies suggested that CuO-NPs have toxic effects, including nephrotoxicity [13], [14], [15]. Recently, great emphasis has been placed on the role of herbal plant extracts as protective agents for various diverse toxins [16].

In addition, there is great support from scientists around the world for employing medicinal plants in developing original medicines with the least possible side effects [17], [18]. Silymarin (SLM), biologically active extract of Silybum marianum (milk thistle) plant, has attracted significant attention for its health benefits against a variety of liver-related toxins [19]. Previous experimental laboratory studies have concluded that SLM is effective in reducing oxidative stress and mitigating cytotoxicity [20], [21]. It is a complex blend of plant-derived compounds with flavonolignans, flavonoids, and polyphenolic molecules that are effective antioxidants. Approximately 60% of the SLM complex is silibinin (silybin), which has many pharmacological effects including antioxidant and anti-inflammatory properties [22]. It also has mitigation susceptibility against the nephrotoxic effects caused by chemicals [23]. This study was done to inspect the potential preventative effect of SLM upon CuO-NPs caused by nephrotoxicity in laboratory rats.

2. METHODOLOGY

2.1. Nanoparticles and Silymarin

A dispersion of CUO nanoparticles (3 wt%) was obtained from Nanoshel (UK) Limited, with the following specifications: color: black, APS: 3–6 nm, solvent: isopropyl alcohol, purity: 99.9%, and PH=3. Besides using Pure Silymarin Envelopes, a dietary supplement available in the markets.

2.2. Animals and Study Design

Twenty-four adult male albino rats, weighing between (190-225) g, were obtained from animal houses designated for scientific research within Iraqi universities. The rats were housed in custom cages of appropriate dimensions under controlled laboratory hygienic conditions (temperature, lighting, and

ventilation), along with easy access to designated food and water. They were acclimated to the laboratory environment for seven days, in preparation for study starting. Equally, all animals were set into four groups of six in each. The study protocol was established according to the administered doses of CuO-NPs and SLM to rats' groups as shown in Table 1.

Dosing continued for 14 consecutive days, and one day after completion, all studied rats were generally anesthetized and dissected. All procedures of this experiment were done in full accordance with the directives of the Ministry of Education and Scientific Research regarding the ethics of dealing with laboratory animals.

Table 1. Animals and Experimental Design

Animals Groups	Treatments and Doses for 14 Uninterrupted Days
CON	Animals received distilled water, served as control.
CUO-NPs	Animals were poisoned with CuO-NPs of 100 mg/kg by gastric gavage [24].
CUO-NPs + SLM	Intoxicated animals with CuO-NPs were provided with SLM of 100 mg/kg orally [25].
SLM	Animals were dosed with SLM of 100 mg/kg only.

2.3. Kidney Function Analysis

Blood samples were collected by cardiac puncture from all studied rats, and the sera were separated by centrifugation for several minutes to check the levels of renal function markers including blood urea nitrogen, creatinine, and uric acid (BU, CR, and UR respectively) measured in mg/dl units, using privet diagnostic kits.

2.4. Oxidative Stress Analysis

Kidney tissues were also acquired from autopsied animals to evaluate oxidative stress in studied rats. Kidney homogenization was performed in a homogenization solution containing appropriate molar amounts of potassium buffer, potassium chloride, and EDTA for one and a half minutes, to obtain kidney tissue supernatants for analysis of levels of glutathione as well as Malondialdehyde (MDA) by measurement of the reactants of thiobarbituric acid reactive substances [26].

2.5. Statistical Analysis

Results were statistically processed by SPSS (version 26), with presented all data as mean and standard deviation (M±SD). To determine the difference between the experimental groups, Tukey test was interpreted post hoc one-way analysis of variance (ANOVA). A P value of ≤ 0.05 was adopted as a significant variation.

3. RESULTS AND DISCUSSION

The results related to the levels of serum indicators of kidney function recorded a significant increase in levels of BU (30.76± 0.93), CR (1.04 ± 0.01), and UR levels (1.74± 0.09) in rats poisoned with CUO-NPs compared to control (20.61±0.74; 0.69±0.03; 1.12± 0.05 respectively).

On other hand, a clear decline in serological levels of these renal markers (25.14±0.54; 0.81± 0.02; and 1.34± 0.04) was observed in CUO-NPs + SLM group compared to CUO-NPs rats. Also, there was no significant difference between the control and the SLM groups, as displayed in Figure 1.

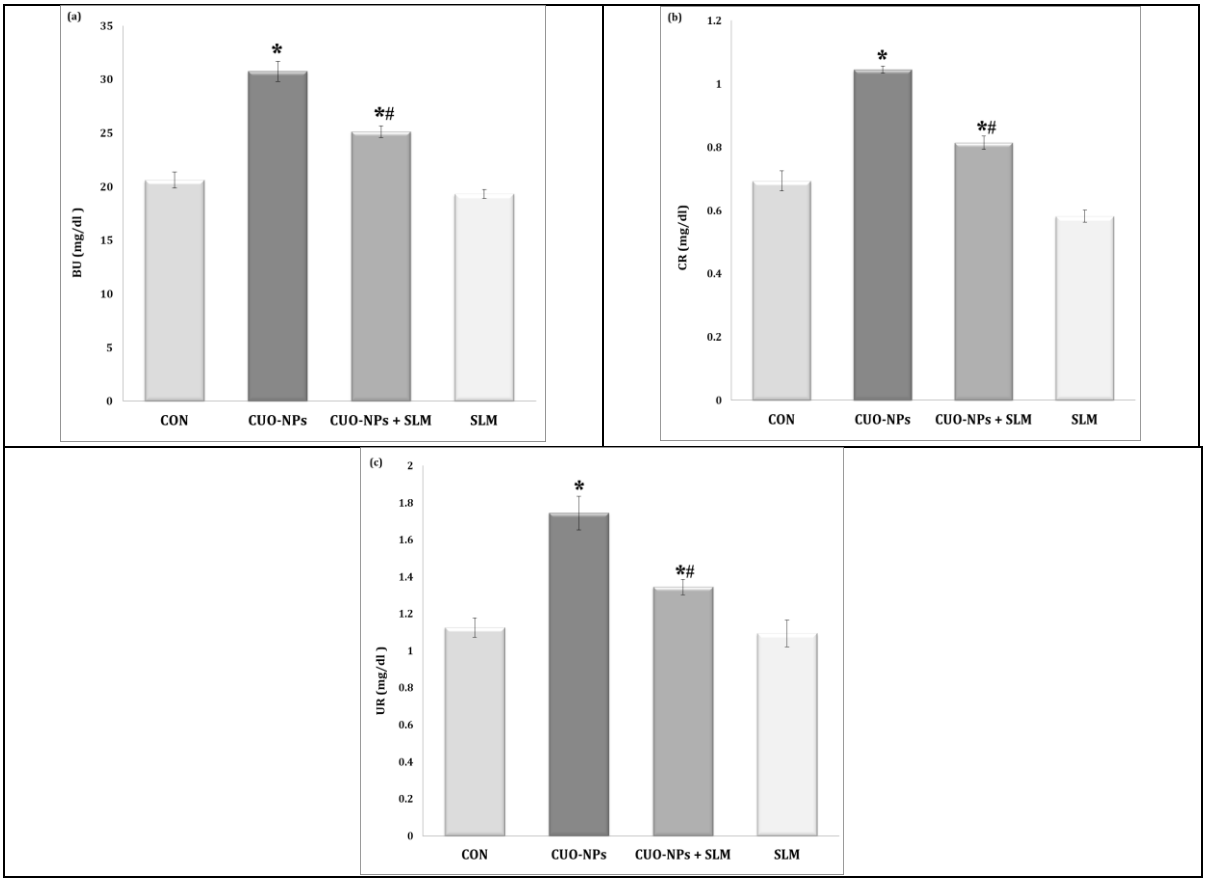

Figure 1. Serum Renal Markers Levels: A) BU, B) CR, and C) UR, For Studied Rats. the Symbol (*) Mark A Significant Variance with CON Group, and (#) Mark A Significant Variance with the Intoxicated CUO-Nps Rats

As for the evaluation of SLM effect on the oxidative stress caused by nanoparticles in the kidney homogenates, it was noted that CUO-NPs induced a higher concentration of MDA metabolites in exposed rats (0.24±0.012) with an apparent reduction in GSH (38.06±4.17) compared to control normal ones (0.09±0.007 and 63.53± 2.28). However, rats treated with CUO-NPs plus SLM manifested respectable amelioration in both oxidative stress indices (0.18±0.006 and 50.04±3.58) compared to rats intoxicated with CUO-NPs as shown in Figure 2.

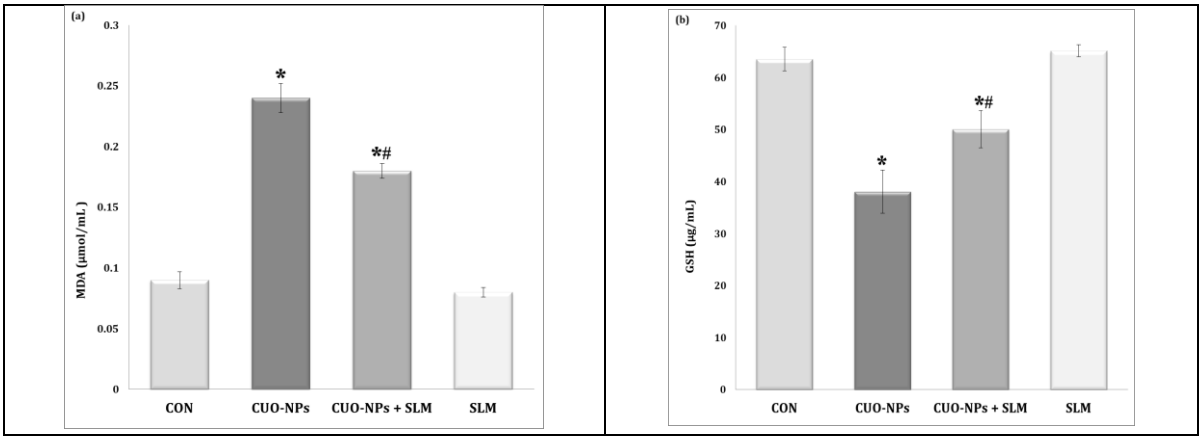

Figure 2. The Values of Oxidative Markers: A) MDA, and B) GSH, for Studied Rats. the Symbol (*) Mark A Significant Variance with CON Group, and (#) Mark A Significant Variance with the Intoxicated CUO-NPs Animals

3.1. Discussion

The results of our study proved that copper oxide nanoparticles dispersion induced clearly renal damage by impairing renal function and stimulating oxidative stress in renal tissue. CUO-NPs increased BU, CR, and UR serum levels notably, and the tissue level of GSH reduced, while MDA elevated markedly. This is in agreement with several previous studies documented that metal NPs may cause oxidative stress, cytotoxicity, and inflammatory processes in vitro as well as in vivo [27], [28], [29], [30]. It is known that the kidney is primary excretory organ in the body for toxins and chemicals, including nanoparticles, after their penetration and distribution in the circulatory system [31], [32]. Upon entry of CuO-NPs through any route of exposure including ingestion into the body, these nanoparticles react either with the acidity of lysosomes or mitochondria, prompting reactive oxygen species ROS) generation, which represents as a compelling approach to linked toxicity with copper oxide nanoparticles. In doing so, it acts as a pro-oxidant, that is, it promotes oxidative stress by stimulating ROS or inactivating antioxidants. Thus, damage to cellular structures as mitochondria and proteins leading to cell death [33], [34], [35]. Several studies have dealt with the toxic effects of CUO nanoparticles on vital organs, including nephrotoxicity. The decrease in glomerular filtration rate in rats intoxicated with CUO-NPs resulted in an increased level of the serum indices BU and CR, indicating impairment of renal function. Otherwise, oxidative stress is a strong potential explanatory cause of renal impairment. As the lipid peroxidase has a deleterious impact on the glomerular basement membrane and thus the renal system [36], [37]. In previous experimental study by on the oral toxicity of CuO nanoparticles in female rats, they suggested that acute and sub-acute high-dose treatments induced significant changes in serological and oxidative stress markers. Establishing that the toxicity observed in in liver, kidney tissues may be due to stimulation of excess ROS producing by CuO-NPs [38]. Another study by, demonstrated adverse effects in rats poisoned with copper oxide NPs orally for 3 months by evaluating indicators of inflammation in the kidneys as well as oxidative stress in laboratory rat [39]. Similarity, concluded in their investigative study that dosing with CuO NPs intraperitoneally for 9 consecutive days has a potential toxicity on liver and kidney tissues of male mature rats that may affect their functions [40]. On other hand, results of this study found an improvement in kidney function indicators and oxidative stress levels in the CUO-NPs + SLM group. This agreement with a previous study conducted by on male rats, they found that SLM reduced the toxic effects of lead acetate by ameliorative functions of the liver and kidneys and their structures by lipid oxidation reduction, attenuating pathological events in tissues structures, and improving antioxidants [41]. In another study conducted by on laboratory rats, they concluded that supplementing vancomycin with silymarin (200 mg) for 8 consecutive days mitigated vancomycin-induced nephrotoxicity by improving oxidative stress perturbations, serum blood nitrogen urea and creatinine levels, and histopathological features [42]. Also, found that dosing of silymarin (100 mg/kg) for seven continues days with colistin was able to produce some amelioration in renal tubular necrosis and significantly augmentation antioxidant capability. The prophylactic ability of SLM increased with higher doses and longer treatment duration to prevent renal toxicity [43]. In previous experimental study on 32 laboratory rats, found that silymarin had a protective effect against renal damage and oxidative stress caused by diclofenac, by decreasing the levels of serum MDA, urea nitrogen, Cr and TNF-α, and relieving histological injuries in the kidneys [44].

4. CONCLUSION

Results of this study approved the deleterious effect of copper oxide nanoparticles on of renal function of the studied laboratory rats. However, combining those nanoparticles with silymarin reduced this toxicity by restoring levels of both serum and oxidative stress renal indices. Thus, silymarin can be considered as a prophylactic agent upon potential nephrotoxicity agents as metal nanoparticles.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Ozdan Akram Ghareeb	✓	✓	✓	✓		✓		✓	✓	✓	✓			
Samed Abduljabbar Ramadhan		✓	✓	✓	✓		✓	✓	✓	✓			✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Informed Consent

All participants were informed about the purpose of the study, and their voluntary consent was obtained prior to data collection.

Ethical Approval

Not Applicable.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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