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ETHANOLIC *SINAPIS ALBA* LEAVES EXTRACT: A NOVEL APPROACH TO COUNTERACTING SODIUM NITRITE-INDUCED INJURY IN EXPERIMENTAL RATS

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ABSTRACT

In light of the increasing trend of using herbal remedies to treat a variety of diseases. This study evaluates the antioxidant qualities present in the ethanolic leaf extract of *Sinapis alba* (*S. alba*). As well as evaluating the content of phenols and flavonoids, and their effectiveness in protecting the heart from heart disease caused by sodium nitrite (SN) in rats (30 mg/kg body weight). Four experimental groups (control, *S. alba*, SN, and *S. alba* + SN) with six rats each were carefully examined over a period of six weeks. The administration of SN significantly increased oxidative stress markers like MDA and LDH and decreased antioxidant enzymes like CAT, GSH, and SOD. It also significantly increased levels of AST, ALT, LDL, cholesterol, triglycerides, and decreased HDL levels. Surprisingly, *S. alba* leaf extract significantly improved these biochemical and cardiac tissue histological changes induced by SN ($P < 0.05$). The study shows unequivocally that *S. alba* ethanolic leaf extract has a strong cardioprotective effect against damage caused by SN.

Keyword: *Sinapis alba* · *sodium nitrite* · *Antioxidants*

INTRODUCTION

Ancient civilizations used nature's pharmacy to treat illness and promote health by using medicinal plants that were prized for their exceptional efficacy and cultural significance. Increasing research demonstrates the medicinal potential of these wonders of nature in treating a variety of ailments while contemporary science explores their

molecular complexity. of these plants **(Kunwar *et al.,* 2013).**

S. alba, sometimes known as white mustard, is a naturally occurring plant found in Asia and Europe. Its leaves are rich in essential minerals, antioxidants, and phytochemicals and studies have demonstrated a variety of health-promoting properties **(Biswal *et al.,* 1982).** The therapeutic qualities of S. alba leaves as a natural remedy for rat illnesses are derived from their biological content. Glucosinolates, flavonoids, and phenolic acids are some of these compounds **(Batool *et al.,* 2024).** These compounds have numerous physiological effects, including anti-inflammatory, antibacterial, antioxidant, and anticancer activities **(Boscaro *et al.,* 2018).** According to **Suvarna *et al.* (2019),** *S. alba* leaves can strengthen rats immune systems, giving them a natural resistance against illness. Furthermore, they have been found to lower blood pressure and the risk of heart disease, which improves cardiovascular health in mice. Sodium nitrite (SN) is largely responsible for the improved taste and appearance of our favorite processed meats. This versatile ingredient is necessary to preserve the meats' mouthwatering pink color, high quality, and long shelf life. It can be found in dishes like hot dogs, beef jerky, and bacon **(Grant and Butler, 1989)**.

Researchers are still working to find out exactly how much sodium nitrite affects human health, particularly in terms of blood pressure, liver function, neurological health, and cardiovascular health **(Akhzari *et al.,* 2024)**. The impact of SN on laboratory rats cardiovascular function was shown by **Laptev *et al.* (2022)**. It has been demonstrated to change heart rates and raise blood pressure. Rats' blood vessel equilibrium is upset by sodium nitrite, which results in atherosclerosis a condition in which plaque builds up inside the arteries, reducing their diameter and obstructing blood flow. Additionally, it builds up in the brain tissue of rats and interferes with normal neuronal function, causing convulsions, abnormal brain functions in humans, and even cell death **(Lijinsky and Kovatch, 1989)**. The aim of this work was to investigate the potential of *S. alba* leaf extracts to protect wounded tissue against the deleterious effects of SN.

MATRIALS AND METHODS

1. Plant material and preparation of plant leaf extract

The *S. alba* leaves were donated by Minia University's Experimental Farm Faculty of Agriculture. According to **Thakur *et al.* (2013)**, ethanol (80%), ethyl acetate, and hexane were used to extract the powdered leaves.

2. Chemicals:

SN was purchased from Sigma, an Egyptian firm.

3. Quantitative examination of phytochemicals

The following techniques were used to evaluate the quantities of total phenolic compounds, flavonoid content, and antioxidant activity (DPPH) of the various solvent extracts of *S. alba*: **Maurya and Singh (2010), Ebrahimzadeh *et al.* (2008), and Brand *et al.* (1995).**

4. High-Performance Liquid Chromatography (HPLC)

A Thermo system (Ultimate 3000) was used to flow the mobile phase at a steady rate of 1.0 milliliter per minute. For twenty minutes, the mobile phase was made up of distilled water (solvent B) and 0.05% trifluoroacetic acid/acetonitrile (solvent A). 18% A and 82% B was the program's progress rate in the first five minutes. Following a seven-minute period, 20% A and 80% B were introduced. Over the following eight minutes, the concentrations of A and B were increased to 40% and 60%, respectively, until they ultimately reached their starting points **(Biswas, 2013).**

5. Experimental animals

Twenty-four male rats weighing 184.2±9 g apiece, all of the Sprague-Dawley strain, were obtained from the Faculty of Pharmacy's Animal House at Al Nahda University, Beni Suef, Egypt. For two weeks, rats were housed in plastic cages in a laboratory environment with air conditioning set to 26 °C ± 2. They were fed a normal pellet diet without any special instructions. Following the guidelines and ethical standards established by the Ethics Committee, the experiment was conducted (Approval No. MU/FA 023/12/22).

6. Experimental design:

After getting used to their new surroundings, the rats were randomly divided into the following four groups, each with six rats:

1) **Control group: Normal rats**

2) **Group *S. alba*:** Rats were given an ethanol leaf extract of *S. alba* orally once a day for six weeks at a dose of 200 mg/kg b.w. **(Thakur *et al*., 2013)**. According to **Walia *et al*. (2011)**, the extract was diluted in 2 milliliters of 2% w/v carboxymethyl cellulose.

3) **Sodium nitrite group (SN):** rats received 30 mg/kg b.w. daily of SN orally for six weeks **(Adel *et al*., 2014).**

4) *S. alba* + SN group: rats were given orally *S. alba* ethanol leaf extract and SN as concentration in group (2) and (3).

At the end of the six-week experiment, diets were taken out of the cages at eight in the morning. By decapitation, blood samples were taken from the retroorbital plexus **(Schermer, 1967)**.

7. Biochemical assays

By centrifuging the blood samples' serum fraction at 4 °C for three minutes at 3000 rpm, a lipid profile as well as liver and kidney function were evaluated. These characteristics were determined by enzymatic colorimetric techniques. Bio-Diagnostic Co., Egypt supplied the kits that were used.

8. Determination of oxidative stress indicators in the heart

Following the procedures outlined by **Marklund and Marklund (1974); Ohkawa et al. (1979); Sulaiman et al. (1994); Beutler et al. (1963); and Aebi (1984)**, in that order, the compounds superoxide dismutase (SOD), malondialdehyde (MDA), lactate dehydroenase (LDH), reduced glutathione (GSH), and catalase (CAT) were chemically evaluated upon

identifying signs of oxidative stress in the heart muscle (myocardium).

9. Preparation of organs for histopathology

For histological examination, tissue slices were cut from a sample of each rat's heart, in accordance with **Ahmed *et al.* (2019)** produced.

10. Statistical analysis

The means (± standard deviation) of six parallel measurements were used to display the experimental findings. Following ANOVA procedures, the analysis of variance was carried out. GraphPad Prism® (GraphPad Software, San Diego, CA, USA) was used to perform statistical calculations **(Motulsky, 1999).**

RESULTS AND DISCUSSION

1- Quantitative analysis of total phenolics and flavonoids content:

Anticarcinogenic, antithrombotic, antiulcer, anti-atherogenic, antiallergenic, anti-inflammatory, antioxidant, immune-modulating, antibacterial, cardioprotective, and analgesic properties are only a few of the health advantages that phenolic compounds offer **(Durazzo *et al.*, 2019)**.

According to GAE, the total phenolic content of *S. alba* extracts ranged from 37.61 mg to 40.46 mg/g (**Table 1**). The highest number of phenolic chemicals (40.46 ± 0.94 mg/g) was detected in the ethanolic extract, which was followed by the ethyl acetate (38.57 ± 0.26 mg/g) and hexane (37.61 ± 0.15 mg/g) extracts. However, the *S. alba* leaf extract's total flavonoid concentration as measured by QE varied from 16.22 mg to 23.13 mg/g. The extract derived from ethanol (23.13 ± 0.21 mg/g) has the highest concentration of total ret

According to **Vergun *et al.* (2019)**, the total phenolic content of the ethanol extract from *S. alba* leaves was 73.58 mg of gallic acid per gram of dry extract, which is in line with our data. However, **Sadowska *et al.* (2023)** found that, depending on the variety and harvest season, the total phenolic content of *S. alba* methanolic leaves extract ranged from 72.97 to 81.35 mg/g.

While, the total amount of flavonoid components in *S. alba alba* leaves ranges from 1.34 to 27.9 mg of QE/g. **(Harbaum *et al.*, 2008)**.

Table 1. Total Phenolic and Total Flavonoids Compounds in *Sinapis* alba Leaf Extracts.

Solvents	Total phenolic compounds (mg/g)*	Total flavonoids (mg/g) **
S. alba ethanol extract	40.46 ± 0.94	23.13 ± 0.21
S. alba ethyl acetate extract	38.57 ± 0.26[a]	20.52 ± 1.04[a]
S. alba hexane extract	37.61 ± 0.15[a]	16.22 ± 0.47[a]

*: mg GAE /g of dry leaves extract; **: mg QE/g of dry leaves extract. Each value is expressed as the mean. SD± (n=4). (a): is significant at $P < 0.05$ vs Sinapis alba leaves ethanol extract.

2. Antioxidant activity:

The color change observed in the solution can be attributed to the antioxidants' conversion of the stable free radical DPPH into 1,1-diphenyl-2-picryl hydrazine **(Kumar *et al.,* 2012)**. **Table 2** illustrates how the DPPH radical scavenging capabilities of *S. alba* leaf extracts increased with concentration for all plant extracts. With the smallest IC50 value of 36.81 µg/mL, the ethanol extract showed the greatest activity in scavenging DPPH radicals from *S. alba* leaves. Next, 69.87 µg/mL of hexane extract and 37.03 µg/mL of ethyl acetate extract were added. As such, the use of ethanol extract enhances the efficiency of phytochemical component extraction from *S. alba*.

Table 2. DPPH Radical Scavenging Activity of *Sinapis alba* Leaves Extracts*.

Solvents	%Inhibition	IC_{50}*(µg/ml)*
Ethyl acetate extract	96.98	37.03
Ethanol 80% extract	97.87	36.81
Hexane extract	54.96	69.87

* The IC50 values correspond to the amount of extract required to scavenge 50% of radicals present in the reaction mixture.

Our findings concur with a study by **Riaz *et al*. (2023)**, which found that the methanolic extract of *S. alba* had an 88.85% DPPH free radical scavenging activity.

3. HPLC analysis of phenolic and flavonoid compounds:

Table 3 displays the phenolic and flavonoid components identified in the *S. alba* leaf ethanol extract as well as the HPLC chromatograms for those compounds. Only a few of the different peaks in the chromatogram were discovered to be present by comparing their retention time with the existing standards. Cinnamic acid (9.99 mg/100 g) and coumaric acid (2.66 mg/100 g) were the two most common phenolic components found in the *S. alba* ethanol extract, whereas diosmin (184.86 mg/100 g) and rutin (8.10 mg/100 g) are the two flavonoid molecules that have been found thus far.

4. Liver biomarkers in rats:

Rats which given SN had significantly higher serum levels of ALT, AST, and ALP indicators ($P < 0.05$) than the control group, with estimated increases of 28.65, 23.29, and 11.06%, respectively. In comparison to the SN group, the group treated with *S. alba* leaf extract demonstrated a reduction in serum ALT levels of about 21.40%, AST levels of 14.25%, and ALP levels of 8.69%. However, when compared to the control group, treatment with ethanolic *S. alba* leaf extract alone did not result in any appreciable changes in any of the indicators **(Table 4).**

Table 3. HPLC Study of the Phenolic and Flavonoid Components in an Ethanol Extract of *Sinapis alba* Leaves.

Compound	Retention Time (min)	Conc. (mg/100 g)
phenolic compounds identified		
Ellagic acid	3.157	0.46
Cinnamic acid	3.363	9.99
Chlorogenic acid	7.013	0.13
Resorcinol	7.507	0.29
Pyrochatechol	10.490	0.15
Vanillic acid	11.450	0.02
Ferulic acid	12.660	0.06
Phenetherine	14.700	0.12
Coumaric acid	15.580	2.66
flavonoid compounds identified		
Rutin	2.437	8.10
Diosmin	3.040	184.86

Table 4. Effect of *S. alba* Leaves Extract on ALT, AST and ALP Levels in Serum Rats Treated with Sodium nitrite.

Group	ALT U/ml	AST U/ml	ALP IU/L
Control	68.40±2.41	173.20± 0.49	145.10±0.24
S. alba	70.52± 0.39	172.30± 0.37	146.69±0.16
SN	88.00±0.79[a]	213.54±0.24[a]	161.16±1.37[a]
***S. alba*+ SN**	69.16± 0.27[c]	183.10±0.99[ac]	147.16±2.031[ac]

Data represent the mean ±S.D. of observations from six rats. [a] Significantly different from control group at $P < 0.05$. [c] Significantly different from sodium nitrite group at $P < 0.05$.

The results of this investigation are consistent with those of studies conducted by **Helal *et al*. (2017)** and **Akhzari *et al*. (2024)**, who also noted a significant increase in AST and ALT activity in the SN-treated group in comparison to the control group. The oxidation of essential iron-containing enzymes, such as cytochrome c, which is involved in oxidation-reduction processes and cellular respiration, may be partially responsible for the deleterious effects of nitrite on the liver **(Helal *et al*., 2008)**.

Changes in these enzymes, including ALT and AST, are frequently associated with injury to the liver or the liver's reaction to toxins. Large concentrations of both are found in the liver, which is why blood serum levels of them rise **(Abou-Hadeed *et al*., 2021)**.

It has been determined that the ethanol leaf extract from *S. alba* possesses antioxidant qualities, which may be responsible for its hepatoprotective benefits. Oxidative stress, a contributing component in numerous liver illnesses, is known to be countered by antioxidants **(Yokozawa *et al*., 2003)**. HPLC results revealed the presence of several active components in *S. alba* ethanol leaf extract, including

ellagic acid, which has been shown to assist in scavenging free radicals, which are dangerous chemicals that can lead to oxidative stress and damage to liver cells **(Zhao et al., 2021)**. Cinnamic acid inhibits hepatic lipogenesis and promotes fatty acid oxidation, which reduces fat accumulation. **Wu *et al.* (2021)** also reported that cinnamic acid improves the management of fatty liver disease by neutralizing these free radicals and supporting liver function. These findings help prevent cellular damage and support liver function.

4. Changes in kidney functions:

The kidney functions levels in blood serum were estimated, and the results showed that compared to the control group, the SN group had statistically significant increases ($P < 0.05$) in blood urea, creatinine, and uric acid levels of about 17.40, 70, and 72.72, respectively (**Table 5**). Comparing *S. alba* to the group receiving SN treatment, these indicators decreased by roughly 8.72, 26.47, and 34.21%, respectively, in a statistically significant ($P < 0.05$) way. The results of this study are consistent with earlier research by **Helal *et al.* (2017)**, which showed that consuming sodium nitrite was associated with a notable increase in blood urea and creatinine levels. **El-Sheikh and Khalil (2011)** also, indicated that kidney function indicators increased after treatment with SN. These inadequacies may be correlated with changes in renal blood flow, glomerular filtration rate, and tubular reabsorption threshold. Our findings concur with those of **Rajamurugan *et al.* (2012)**, who showed that giving a *S. alba* leaf extract to rats treated with galactosamine reduced blood levels of urea, creatinine, and uric acid.

Our findings show that there are phenolic components present in the ethanol *S. alba* leaf extract. Because phenolic chemicals have anti-inflammatory qualities, kidney inflammation may be lessened. According to **Liu *et al.* (2023)**, phenolic substances help preserve renal function by lowering inflammation, which is linked to the development of certain kidney disorders. Research has examined the potential preventive function of cinnamic acid, as identified in our HPLC data, against nephrotoxicity caused by agents such as kidney damage generated by cisplatin **(El-Sayed *et al.*, 2013)**.

Table 5. Effect of *S. alba* Leaves Extract on Urea, Creatinine and Uric acid Levels in Serum Rats Treated with Sodium nitrite.

Group	Urea mg/dl	Creatinine mg/dl	Uric acid mg/dl
Control	29.88±0.19	0.20±0.016	1.10±0.026
S. alba	31.08±1.13	0.23±0.028	1.04±0.016
SN	35.08±1.02[a]	0.34±0.017[a]	1.90±0.059[a]
***S. alba*+ SN**	32.02±0.15[c]	0.25±0.026[ac]	1.25±0.031[ac]

Data represent the mean ±S.D. of observations from six rats. [a] Significantly different from control group at $P < 0.05$. [c] Significantly different from sodium nitrite group at $P < 0.05$.

6. Lipid profile assessment:

Rats treated with ethanol *S. alba* leaf extract alone did not show any significant ($p<0.05$) alterations in their lipid profile levels when compared to the control group (**Table 6**). In contrast to the control group, the SN group exhibited a substantial ($p<0.05$) decline in HDL levels to roughly 34.22% and a significant ($p<0.05$) increase in TC, TG, LDL, and VLDL levels to approximately 51.91, 93, 95, and 163%, respectively. When compared to the SN group, the pretreatment groups with ethanol *S. alba* showed a substantial ($p<0.05$) decrease in TC (2.33%), TG (16.77%), LDL (6.20%), and VLDL (32.15%).

These results are consistent with those of **Helal *et al*. (2017)**, who discovered that, in contrast to the control group, treated groups with SN showed highly significant increases in TC, TG, LDL, and VLDL levels ($p<0.001$) and decreases in HDL ($p<0.001$). It has also been suggested that the higher serum cholesterol levels seen in rats could be caused by the peroxidation of lipids in cell membranes.

Table 6. Effect of *S. alba* Leaves Extract on TC, TG, HDL, LDL and VLDL Levels in Blood Serum of Rats Treated with Sodium nitrite

Groups	TC mg/dl	TG mg/dl	HDL-c mg/dl	LDL-c mg/dl	VLDL-c mg/dl
Control	52.24±1.42	64.40±2.34	34.54±2.13	12.46±1.72	9.48±1.71
S. alba	54.42±2.54	67.50±3.27	36.56±3.78	15.54±3.03	12.56±1.42
SN	79.36±2.17[a]	124.0±2.51[a]	22.72±2.73[a]	24.35±0.04[a]	24.94±2.42[a]
S. alba+ SN	77.51±4.16[ac]	103.2±2.19[ac]	25.45±3.09[a]	22.84±1.60[a]	16.92±3.05[ac]

Data represent the mean ±S.D. of observations from six rats. [a] Significantly different from control group at $P < 0.05$. [c] Significantly different from sodium nitrite group at $P < 0.05$.

7. Oxidative stress parameters:

The oxidative stress caused by SN in the hearts of the rodents was measured using MDA, GSH, CAT, SOD, and LDH measurements. **Table 7** shows that SN significantly ($P<0.05$) increased MDA and LDH relative to the control group by about 86.53% and 228.57%, respectively, while decreasing GSH, CAT, and SOD relative to the control group by about 71.21%, 32.69%, and 49.19%, respectively. On the other hand, compared to the group receiving SN treatment alone, pretreatment of rats with a *S. alba* ethanol extract containing demonstrated significant protection against SN intoxication, as demonstrated by a significant increase in levels of GSH, CAT, and SOD and a significant decrease in levels of LDH and MDA. Additionally, there were no statistically significant differences between the control group and the experimental group that received *S. alba* ethanol extract in terms of oxidative stress indicators. Our results suggest that plasma SN-inhibited GSH and CAT enzyme activity may be linked to the observed increase in lipid peroxidation (**El-Sheikh and Khalil, 2011**).

Table 7. Effect of *S. alba* Leaves Extract on MDA, GSH, CAT, SOD and LDH Levels in Rats Heart Injected with Sodium nitrite.

Groups	MDA nmole/g	GSH mg/g	CAT U/L	SOD mg/g	LDH U/L
Control	5.05±0.74	38.60±2.25	8.90±0.96	22.44±0.49	630.0±10.00
S. alba	5.45±1.21	36.50±2.36	8.57±0.74	22.44±1.04	618.0±14.40
SN	9.42±2.49[a]	11.11±1.42[a]	5.99±0.08[a]	11.40±0.96[a]	2070±103.7[a]
S. alba+ SN	7.40±1.74	23.37±1.87[ac]	8.30±0.27[ac]	21.11±0.32[c]	680.0±15.81[c]

Data represent the mean ±S.D. of observations from six rats. [a] Significantly different from control group at $P < 0.05$. [c] Significantly different from sodium nitrite group at $P < 0.05$.

According to **Nakagawa and Tayama (1988)**, streptozotocin-induced diabetic cataract in Wistar rats was lessened by S. alba extract (500 mg/kg b.w.). This effect was observed in MDA, GSH, and antioxidant enzymes. Serum urea, creatinine, and MDA levels decreased after receiving *S. alba* after an hour-long cadmium chloride injection, as shown by **Al-Diwan *et al*. (2020)**. The Brassicaceae family of plants contains active phytochemicals such as phenols, indoles, glucosinolates, and aromatic compounds, which may have contributed to this reduction. The variations in enzyme levels are also believed to be caused by these phytochemicals. According to **Wahjuni *et al*. (2019)**, the SOD level was raised by an ethanol extract of mustard green leaves. The authors also suggested that the extract's compounds some of which may have antioxidant and antihyperglycemic properties were the cause of the extract's SOD-raising activity.

8. Histopathological examination of the heart

Rat hearts (**Fig. 1**) from the group control negative underwent microscopic analysis, which showed that the cardiomyocytes' histological architecture was normal. Rats from Group *S. alba* also showed histologically normal heart tissue in cardiac sections. Other than that, the hearts of the rats in group SN displayed histological alterations that were defined by edematous fluid between the cardiomyocytes, focal inflammatory cell infiltration, and noticeable vacuolization of the cardiomyocyte sarcoplasm. Rats from groups SN and *S. alba*, on the other hand, had hearts that showed very minor alterations; histological examination of the sections that were studied indicated no abnormalities other than a small amount of intramyocardial edema and minimal myocardial blood vessel congestion in certain areas.

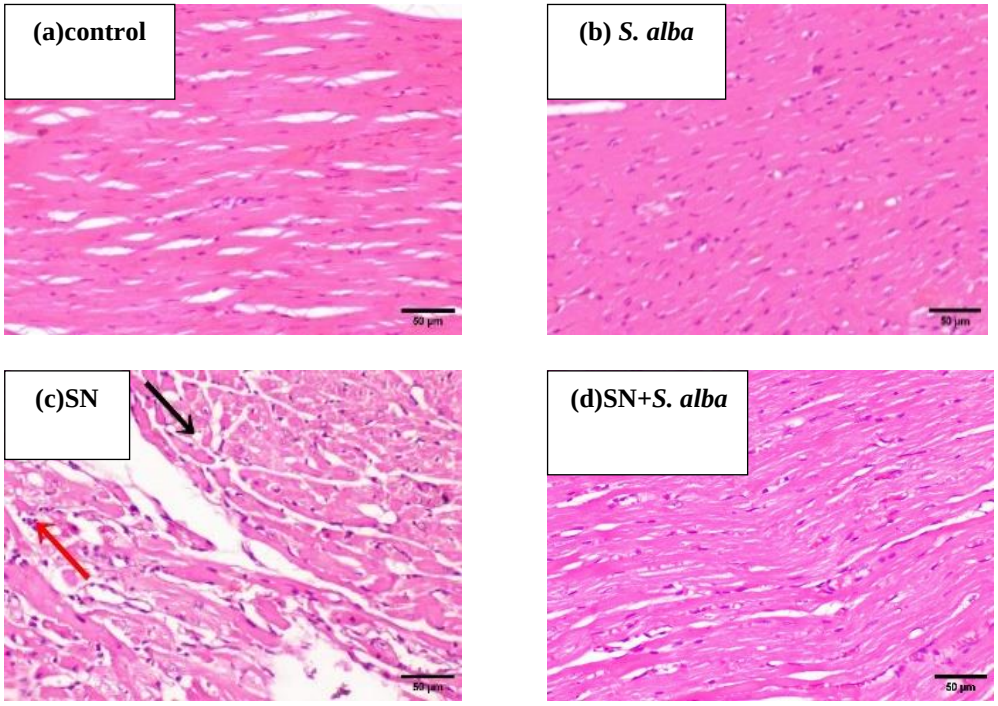

Fig. 1. Photomicrograph of the cross section in the heart cortex of control, *S. alba*, SN, and SN+ *S(a):* control group showing the normal histological architecture of cardiomyocytes, (b): group *S. alba* showing histologically normal cardiac tissue, (c): group SN showing marked vacuolization of the sarcoplasm of cardiomyocytes (black arrow) and focal inflammatory cells infiltration (red arrow), (d): group SN+ *S. alba* showing no histopathological changes.

CONCLUSION

The results of this study highlight the powerful protective benefits of *S. alba* ethanol leaf extract in mitigating the harmful effects of SN on the histology of the rat heart. *via* modifying the activity of vital antioxidant enzymes and markedly enhancing a variety of biochemical and histopathological indicators. Thus, the *S. alba* leaf extract is shown to be a promising therapeutic agent for the prevention and treatment of heart damage caused by toxic substances in addition to being a strong natural antioxidant.

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الملخص العربى

مستخلص أوراق الخردل الإيثانولى : نهج جديد لمواجهة الإصابة الناجمة عن نتريت الصوديوم في الفئران التجريبية

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في ظل الاتجاه المتزايد لاستخدام العلاجات العشبية لعلاج مجموعة متنوعة من الأمراض. تقوم هذه الدراسة بتقييم الصفات المضادة للأكسدة الموجودة في مستخلص أوراق الإيثانول لنبات الخردل *S. alba* وكذلك تقييم محتوى الفينولات والفلافونويدات ومدى فاعليتها في حماية القلب من أمراض القلب الناتجة عن نتريت الصوديوم (SN) في الجرذان (30 ملغم/كغم من وزن الجسم). تم فحص أربع مجموعات تجريبية (الكونترول، الخردل، نيتريت الصوديوم، الخردل + نيتريت الصوديوم). مع ستة فئران لكل منها بعناية على مدى ستة أسابيع. أدى تناول SN إلى زيادة كبيرة في علامات الإجهاد التأكسدي مثل MDA وLDH وانخفاض الإنزيمات المضادة للأكسدة مثل CAT وGSH وSOD. كما أنه أدى إلى زيادة كبيرة في مستويات AST وALT وLDL والكوليسترول والدهون الثلاثية وHDL وانخفاض مستويات HDL. والمثير للدهشة أن مستخلص أوراق الخردل قلل بشكل كبير من هذه التغيرات النسيجية للأنسجة البيوكيميائية والقلبية الناجمة عن SN ($P < 0.05$). تظهر الدراسة بشكل لا لبس فيه أن مستخلص أوراق الخردل الإيثانولي له تأثير قوي وقائي للقلب ضد الأضرار الناجمة عن SN.