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Abstract:

The purpose of this study was to investigate the impact of using the powder and the ethanolic extract of eggplant leaves and peels on liver and kidney functions and the antioxidant enzymes; superoxide dismutase (SOD) and glutathione peroxidase (GPX), in addition to an inflammatory marker; C-reactive protein (CRP). Phytochemical screening of the ethanolic extract of both leaves and peels was carried out. Also, their content of phenolic compounds, flavonoids, and anthocyanins was determined. In the animal experiment, 30 rats were divided into six groups (5 rats each); one group received a basal diet only (normal control). The remaining five groups were injected (IP) with cisplatin to induce hepato-nephrotoxicity; one remained on a basal diet and was considered a positive control. Two injured groups received the powder of leaves and peels, while the other two groups received the extracts of leaves and peels of eggplant. Rats were sacrificed after 28 days, and their blood was drawn for analysis. The phytochemical screening results indicated the presence of flavonoids, tannins, glycosides, saponins, and alkaloids. The results showed that the content of phenolic and flavonoid compounds was higher in the leaf than in the peel. On the contrary, the anthocyanin content of the peel was higher than that of the leaf. Regarding liver and kidney functions, the findings showed significant decreases in ALT, AST, and bilirubin and a substantial increase in serum total protein in the groups treated with the peel and leaf extracts. Also, a significant reduction in their serum creatinine, urea, and uric acid was observed compared to the positive control. However, the powder and extract

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of the leaves and peels of eggplant revealed significant increases in serum superoxide dismutase and glutathione peroxidase levels in the treated groups compared to the positive control group. At the same time, all four treated groups decreased the blood content of c-reactive protein significantly. The results revealed that the ethanolic extract of the leaves and peels was more effective than the powder in reducing hepato-nephrotoxicity.

Keywords: nephrotoxicity, hepatotoxicity, cisplatin, liver, kidney, eggplant, antioxidant enzymes.

1. INTRODUCTION

Eggplant (*Solanum melongena*) is a vegetable crop that grows worldwide and can supply significant alimentary benefits because of its high content of vitamins, phenolics, and antioxidants. Furthermore, eggplant has potential pharmaceutical applications **(Gürbüz *et al*., 2018).** It is one of the vegetables with the highest antioxidant total capacity. It contains high levels of phytochemicals such as flavonoid compounds and phenolic acids, both of which have strong antioxidant properties **(Zaki and Nasef 2018).** Eggplant peel is a rich source of biologically active substances (anthocyanins). It contains a high level of antioxidants, so it is considered to have a great role in the prevention of free radicals and thus diseases **(Basuny *et al*., 2012).** Purple eggplant (Solanum melongena) peels have been used in the treatment of various metabolic disorders, proliferative damages, and degenerative changes due to ageing and senescence. The human body's cells suffer damage caused by reactive species generated by some metabolic processes. Such chemically unstable species are called free radicals, and antioxidants can protect and repair the body from damage. They work by slowing or preventing the formation of free radicals, and purple fruit peel extract has a hepatoprotective function whereas peels have very high antioxidant efficacy **(Sarkar *et al*., 2019).** The leaves of eggplant are considered extremely nutritious and are used in preparing stews and soups. The leaves are rich in zinc, crude fiber, fat, protein, and calcium, and are found to contain appreciable amounts of the amino acid methionine. The leaves are used for a variety of medicinal purposes, including treating throat problems in Sierra

Leone and stomach problems in Kenya, and toothaches are also treated with them **(Komlaga *et al*., 2014).** Crude alkaloidal fraction isolated from the leaves of *S. melongena* exhibited significant analgesic effects and some CNS depressant effects **(Salama and Ezzat, 2013).** The liver is the organ responsible for regulating the body's internal environment. Currently, there is no way to compensate for the loss of liver function, and it also significantly affects nutrient flow and regulates carbohydrate, protein, and fat metabolism. Drugs are a significant cause of liver damage, and over 900 drugs, toxins, and herbs have been linked to liver damage. Approximately 75% of all idiosyncratic drug reactions lead to liver death or transplantation. Some examples are liver tumors, active chronic hepatitis, liver cirrhosis, acute fatty infiltration, liver granulomas, cholestatic jaundice, and other drug-induced liver diseases **(Pandit *et al*., 2012).** The kidney is the organ responsible for a diversity of essential functions in the human body, including detoxification, regulation of extracellular fluids, homeostasis, and excretion of toxic metabolites **(Stevens *et al*., 2006)**. Nephrotoxicity refers to a rapid decline in kidney function caused by the toxic effects of chemicals and medications. There are several types, and some drugs may have multiple effects on renal function. Substances that cause nephrotoxicity are known as nephrotoxins. Renal tubular toxicity, inflammation, glomerular damage, crystal nephropathy, and thrombotic microangiopathy are just a few of the mechanisms that cause nephrotoxicity. Serum creatinine and blood urea are the traditional signs for detecting nephrotoxicity and kidney dysfunction **(Al-Naimi *et al*., 2019).** Cisplatin is an antineoplastic drug based on platinum that was first approved in 1978. Today, it is still an effective and essential treatment for various cancers **(Manohar and Leung, 2018).** Nephrotoxicity, nausea, hepatotoxicity, neurotoxicity, and cardiotoxicity are just a few of the drug cisplatin's toxic side effects **(Aldossary, 2019).** In this study, we aimed to evaluate how eggplant peels and leaves can alleviate cisplatin toxicity in rats.

2. MATERIALS AND METHODS

2.1. Materials:

- **Plant:** Fruits and fresh leaves of *Solanum melongena* were collected from the garden of the Faculty of Science affiliating with the Department of Botany at Mansoura University.
- **Chemicals:** All chemicals were purchased from Elgomhoria Company for medicine and medical devices in Mansoura City, Dakahlia Governorate, Egypt.
- **Cisplatin:** drug (Mylan S-A-S-France) was purchased from a pharmacy in Mansoura at a concentration of 50 mg/50 ml.
- **Animals:** Thirty healthy adult male white albino rats, weighing 110 ± 5 g, were purchased from Vaccines and Drug Company (VAC), Giza, Egypt. (Guidelines for ethical conduct in the care and use of animals in research were obtained from the Scientific Research Ethics Committee of Mansoura University).

2.2. Methods:

2.2.1. Preparation of the powder of eggplant peel and leaves:

The eggplant and fresh leaves were thoroughly washed in water, and the peels were separated by using a knife. Then it was dried at 40 °C in the oven (to avoid spoilage of the phenol content) to a constant weight. The leaves were dried in the open air. After drying, the peels and leaves were ground into a powder.

2.2.2. Preparation of the ethanolic extract of eggplant peel and leaves:

250 g of each powder of peels and leaves of eggplant were soaked in 1L ethanol and mixed well, then left overnight and filtered through filter paper. The filtrate was kept in a dark bottle. Another portion of ethanol was added to the residue, shaken well, left overnight, then filtered and the filtrate was added to the previous filtrate. The residue was resoaked in ethanol overnight and filtered. All the three filtrates were collected to make the ethanolic extract solution. The solvent was removed by means of evaporation using a rotary evaporator. The obtained extract was collected

and dried in a desiccator to a constant weight, then kept in dark bottles until use.

2.2.3. Chemical analysis:

- **Phytochemical screening of crude ethanolic extracts:**
  - The presence of saponins, alkaloids, and flavonoids was determined using the method of **Arefin *et al*. (2015).**
  - The presence of steroids, phenols, tannins, and terpenes was examined by the method detailed by **Usharani *et al*. (2016).**
  - Glycosides were detected using Molish's reagent according to **Ashtalakshmi and Prabakaran (2015).**
- **Determination of total polyphenols and flavonoids:**
  - **Total polyphenol:** Using the Folin–Ciocalteau reagent, total polyphenol content was determined, as mentioned by **Limmongkon *et al*. (2017)**.
  - **Total flavonoids:** With few modifications, the aluminium chloride colorimetric technique described by **Munhoz *et al*. (2014)** was used to determine total flavonoid concentration.
  - **Anthocyanins:** Anthocyanins concentration was determined as described by **Mancinelli (1984).**

2.2.4. The basal diet:

The basal diet was prepared according to the National Research Conical **NRC, 1995)**. All the biological experimental procedures were applied in accordance with international guidelines for the care and use of laboratory animals. Ethical guidelines were maintained during animal handling and permission was obtained from the concerned department.

2.2.5. Induction of nephrotoxicity and hepatotoxicity:

Hepato-nephrotoxicity was induced in rats by injecting a single dose of cisplatin intraperitoneally in a dose of 10 mg/kg b.wt. on the first day, according to **Un *et al*. (2020)**.

2.2.6. Experiment design:

After a week adaptation period, rats were classified into six groups (five rats each), one of them remained on the basal diet only and served as

normal control (Group1). The rest 5 groups were injected with cisplatin (10 mg/kg. bw) intraperitoneally to induce hepato-nephrotoxicity. One of these injured groups remained on the basal diet and was considered a positive control (Group 2). The other four injured groups were treated with the powder and extract of the eggplant leaves and peels as follows:

Group 3 (leaves powder): Fed on a diet containing leaves powder at a concentration of 35 gm/kg feed.

Group 4 (peel powder): Fed on a diet containing peel powder at a concentration of 35 gm/kg feed.

Group 5 (leaves extract): Received leaves extract daily in a dose of 250 mg/kg b.w orally through a stomach tube.

Group 6 (peel extract): Received peel extract daily in a dose of 250 mg/kg b.w. orally through a stomach tube.

Daily food intake and weekly body weight gain were recorded. After 28 days, the rats were anaesthetized, and blood samples were collected in clean centrifuge tubes to obtain serum.

2.2.7. Biological estimations:

- **Biochemical analysis of serum:**
  - Alanine aminotransferase (ALT), and aspartate aminotransferase (AST), were assayed according to the methods described by **Bergmeyer and Horder (1980)**
  - Total bilirubin in plasma was determined according to **Walters and Gerade (1970).**
  - Total protein (TP) was estimated using the Biuret method according to **Armstrong and Carr (1964).**
  - Creatine and urea levels were estimated in plasma according to **Henry *et al*. (1974) and Patton and Crouch (1977).**
  - Serum uric acid was estimated according to **Fossatti *et al*. (1980).**
  - Superoxide dismutase (SOD) was estimated according to **Sarkar *et al*. (2020).**

- Serum glutathione peroxidase (GPX) was estimated according to **Moin (1986).**

- C-reactive protein (CRP) was estimated according to **Fagan *et al*. (1982).**

2.2.8. Statistical analysis:

All tests were accomplished using the computer package of the statistical analysis program (SPSS, version 24, 2016)., the collected data was presented as means ± standard deviations (means ± SD), statistically analyzed using one-way analysis of Variance (ANOVA), and the means between groups were compared by least significant difference (LSD) statistic test, according to **Artmitage and Berry (1987).**

3. RESULTS AND DISCUSSION

3.1. Phytochemical screening of the alcoholic extract of leaves and peels of eggplant

The data in Table (1) shows the phytochemical screening of the ethanolic extract of eggplant leaves and peels. The data provides evidence of the presence of flavonoids, tannins, glycosides, saponins, and alkaloids in the extracts of leaves and peels. The leaf extract has high levels of flavonoids, tannins, and glycosides and low levels of saponins and alkaloids. On the other hand, the peel extract contains high levels of saponins, alkaloids, tannins, and glycosides and fewer levels of flavonoids. These results were in good agreement with those obtained by **Febriza *et al*. (2021)**, who found that purple eggplant peel extract contains active substances flavonoids, tannins, and saponins. They mentioned that purple eggplant peel extract with 25%, 50%, and 75% concentrations has the same ability as nystatin in inhibiting the growth of *C. albicans* (the fungus that most commonly causes superficial mucosal infections in humans).

Table 1: Phytochemical screening of leaves and peel extract of eggplant

Components / Samples	saponins	Flavonoids	alkaloids	tannins	Glycosides carbohydrates
Leaves	+	++	+	++	++
Peels	++	+	++	++	++

3.2. Total phenols, flavonoids, and anthocyanins in ethanolic extracts of eggplant leaves and peels

The data in Table (2) show the total phenols, flavonoids, and anthocyanins in the leaves and peel extracts of eggplant. The data showed that the content of phenolic and flavonoid compounds in the leaf extract was higher than in the peel extract, where the total phenol content was 18.1 mg GAE/g in leaves and 16.7 mg GAE/g in peels. On the other hand, the total flavonoid content was 7.75 mg QE/g in leaves and 6.18 mg QE/g in peels. The results showed that the anthocyanins content of peel extract (150.9 mg/100g) was higher than that in leaves extract (107.6 mg/100g). The high content of polyphenols, especially anthocyanins, plays an essential role in the vital activity of leaves and peels of eggplant.

In this respect, **Adewale *et al*. (2014)** found that *S. macrocarpon* leaves showed high flavonoid and phenolic content. The water leaf extract of *Solanum macrocarpon* possesses powerful antioxidant activity and can offer good protection against oxidative damage to cells in the body, especially the liver and brain. According to **Doulabi *et al*. (2020)**, the eggplant peel was observed to be rich in phenolic and flavonoid compounds and anthocyanins with high DPPH radical-scavenging activity. **Bouhajeb *et al*. (2020)** highlighted that *S. melongena* leaves, until now considered no more than a standard agricultural by-product contain a wide range of biologically active compounds, such as high levels of total phenols and tannins, and this was true in all the studied cultivars.

Table 2: Total phenols, flavonoids, and anthocyanins in ethanolic extracts of eggplant leaves and peels

Components / Samples	Total phenols (mg GAE /g)	Flavonoids (mg QE/g)	Anthocyanins (mg/100g)
Leaves	**18.10**	**7.75**	**107.6**
Peels	**16.70**	**6.18**	**150.9**

3.3. Effect of the powder and extract of eggplant leaves and peels on liver function tests in rats with cisplatin-induced hepatonephrotoxicity.

The data in Table (3) showed that the cisplatin group (positive control) has high significant levels of serum ALT, AST, bilirubin (BIL), and a lower level of total protein (TP) as compared to normal control at $p \leq 0.05$.

Regarding ALT levels, it was noticed that the best group which revealed the lowest decrease in serum ALT was the peel extract group (37.33 ± 4.5 U/L), followed by the leaves extract group (43.67 ± 2.1 U/L), while the peel powder group and the leaves powder group showed non-significant decreases as compared to the positive control group (51.33 ± 3.1 U/L) at $p \leq 0.05$.

Concerning serum AST level, it was noticed that the most effective group which revealed the lowest decrease in serum AST was the leaves extract group (109.33 ± 8.6 U/L), followed by the peel extract group (121.67 ± 6.7 U/L), and then the leaves powder group (136 ± 11.8 U/L), while the peel powder group (150.33 ± 8 U/L) showed a non-significant decrease as compared to the positive control group (164.67 ± 13.3 U/L). As for bilirubin (BIL) level, it was noticed that the group that revealed the most significant decrease in serum bilirubin was the peel extract group (0.38 ± 0.07 U/L), followed by the leaves extract group (0.40 ± 0.04 U/L), and then, the leaves powder group (0.41 ± 0.03 U/L), finally the peel powder group (0.50 ± 0.04 U/L) compared to the positive control group (0.70 ± 0.07 U/L).

Concerning total protein (TP) level, it was noticed that the best groups that revealed the highest increase in serum (TP) were both the peel extract group (6.7 ± 0.06 U/L) and the leaves extract group (6.7 ± 0.11 U/L), followed by the peel powder group (6.6 ± 0.08 U/L) and finally, the leaves powder group (6.4 ± 0.10 U/L) when compared with the positive control group (5.3 ± 0.09 U/L) at $p<0.05$.

The findings suggest that eggplant leaves and peels may serve as both a preventive and therapeutic agent for healthy individuals as well as those with liver disease, especially those experiencing hepatotoxicity. Additionally, due to their high contents of fiber, phenolic compounds,

flavonoids, and anthocyanins, eggplant leaves and peels could provide a foundation for the development of drugs aimed at treating oxidative stress and related disorders.

These results are in agreement with **Sarkar *et al*. (2020)**, who found that oral administration of 100, 200, and 400 mg/kg doses of the extracts of purple peels of *Solanum melongena* significantly reduced the elevated levels of serum ALT, AST, and bilirubin levels in hepatotoxic rats.

According to **Zaki and Nasef (2018)**, eggplant peel powder significantly reduces the liver enzymes ALT and AST. Furthermore, **Elasoru *et al*. (2017)** discovered that combining D-galactose with an extract of *Solanum macrocarpon* leaves significantly reduced elevated levels of ALT and AST and increased serum hepatic total protein concentrations.

According to **Adewale *et al*. (2015)**, an aqueous extract of *Solanum macrocarpon* at 250 mg/kg, 500 mg/kg, and 750 mg/kg body weight resulted in a significant decrease in the activities of the enzymes ALT and AST, as well as a significant increase in total protein levels.

Based on a study by **Ekweogu *et al*. (2020)**, significant ($P < 0.05$) decreases in serum levels of AST, ALT, and total bilirubin, conjugated and unconjugated bilirubin were observed in rats treated with aqueous leaf extract of *S. aethiopicum* in both male and female rats compared to the control. This suggests that the extract at the given doses did not cause any liver damage, but rather possessed hepato-protective properties.

Table 3: Effect of the powder and extract of eggplant leaves and peels on liver function parameters in rats with cisplatin-induced hepatonephrotoxicity.

Parameters / Group	ALT (U/L)	AST (U/L)	BIL (mg/dl)	T.P (g/dl)
Normal control (-ve)	33.67 ± 4.2 ^{d}	107.33 ± 6 ^{d}	0.34 ± 0.04 ^{c}	7.05 ± 0.11^{a}
Positive control (+ve)	51.33 ± 3.1^{a}	164.67 ± 13.3 ^{a}	0.70 ± 0.07 ^{a}	5.33 ± 0.09 ^{e}
Leaves powder	49.00 ± 4 ^{ab}	136.00 ± 11.8 ^{bc}	0.41 ± 0.03 ^{bc}	6.42 ± 0.10 ^{d}
Peels powder	46.67 ± 4.5 ^{ab}	150.33 ± 8 ^{ab}	0.50 ± 0.04 ^{b}	6.59 ± 0.08 ^{c}
Leaves extract	43.67 ± 2.1 ^{bc}	109.33 ± 8.6 ^{d}	0.40 ± 0.04 ^{c}	6.72 ± 0.11 ^{b}
Peels extract	37.33 ± 4.5 ^{cd}	121.67 ± 6.7 ^{cd}	0.38 ± 0.07 ^{c}	6.74 ± 0.06 ^{b}

Each value is the mean ± SD

The values in each column with different superscripts are significantly different at $p \leq 0.05$.

3.4. Effect of the powder and extracts of eggplant leaves and peels on kidney function tests in rats with cisplatin-induced hepatonephrotoxicity.

The results in Table (4) showed the effects of the powder and the ethanolic extract of both leaves and peels of eggplant on serum creatinine, urea, and uric acid in the cisplatin-induced hepato-nephrotoxicity rats.

As evident from the positive group results, the cisplatin drug caused significant increases in serum levels of creatinine, urea, and uric acid compared to the normal control group. Their increase percentages reached 186, 163, and 125%, respectively.

The peel extract decreased serum creatinine to the lowest value (0.74 ± 0.04 mg/dl) among the four treated groups in a percentage of 57%,

followed by the leaves extract (0.80 ± 0.02 mg/dl) in a ratio of 53% reduction. On the other hand, the serum urea levels in the groups treated with peel extract and peel powder decreased significantly compared to the positive control group. Their respective decrease percentages were 53 and 36%.

Regarding the serum levels of uric acid, it was noticed that the most effective group that showed the most significant decrease in serum uric acid was the leaves extract group (2.7 ± 0.16 mg/dl), followed by the peel extract group (2.8 ± 0.15 mg/dl) as compared to the positive control group (4.8 ± 0.18 mg/dl).

However, the groups that fed on the powder of peels and leaves showed significant decreases in serum creatinine, urea, and uric acid compared to the positive control group, and the peel powder was better than the powder of the leaves in this respect.

These good results refer to the ability of eggplant peel and leaves to reduce the toxic effects of hepatonephrotoxicity in the kidney. **Elasoru *et al*. (2017)** found that the ability of FRESML (Flavonoid-Rich Extract of *Solanum macrocarpon* Leaves) to restore the levels of urea and creatinine to nearly control levels in the treated group suggests the ability of the extract to prevent amino acid deamination (nephroprotective) and could be credited to its antioxidant activities.

Based on a study by **Ozioko *et al*. (2020)**, they found that the therapeutic administration of *Solanum marcrocarpon* alleviated paracetamol-induced kidney toxicity. This could be due to the anti-inflammatory and antioxidant effects of the different compounds (alkaloids, saponins, flavonoids, tannins, and cardiac glycosides).

Ekakitie *et al*. (2021) reported that oral administration (especially at the highest dose of 49.8 mg/kg) of aqueous extract of *Solanum macrocarpon* leaves demonstrates anti-nephropathy by reducing the elevated creatinine, uric acid, and urea levels in diabetic rats to the normal values. The brilliant performance of the aqueous extract represents in

reducing serum creatinine, urea, and uric acid. This also supports the anti-nephropathy potential of the extract.

Another study showed a significant decrease in the levels of urea, creatinine, sodium and potassium in the male and female animals treated with 200 mg/kg and 400 mg/kg of the aqueous extract of *Solanum macrocarpon*. This suggests that *S. aethiopicum* does not have a negative effect but rather can protect the kidneys against toxic substances. The extracts enhanced the ability of the kidneys to excrete these toxic wastes (urea, creatinine) and did not cause renal damage or impairment in both males or females **(Ekweogu *et al*. 2020)**.

Table 4: Effect of the powder and extract of eggplant leaves and peels on serum creatinine, urea, and uric acid in rats with cisplatin-induced hepatonephrotoxicity.

Parameters / Groups	Creatinine (mg/dl)	Change %*	Urea (mg/dl)	Change %*	Uric acid (mg/dl)	Change %*
Normal control (-ve)	0.60 ± 0.04 ^{e}		35.33 ± 5.5 ^{d}		2.11 ± 0.08 ^{e}	
Positive control (+ve)	1.72 ± 0.02 ^{a}	+186%**	93.00 ± 5 ^{a}	+163%**	4.74 ± 0.18 ^{a}	+125%**
Leaves powder	1.38 ± 0.10 ^{b}	- 20%	74.00 ± 4.6 ^{b}	- 20%	3.55 ± 0.09 ^{b}	- 25%
Peels powder	0.98 ± 0.06 ^{c}	- 43%	59.33 ± 4.5 ^{c}	- 36%	3.07 ± 0.18 ^{c}	- 35%
Leaves extract	0.80 ± 0.02 ^{d}	- 53%	61.33 ± 4 ^{c}	- 34%	2.71 ± 0.16 ^{d}	- 43%
Peels extract	0.74 ± 0.04 ^{d}	- 57%	43.67 ± 4 ^{d}	- 53%	2.81 ± 0.15 ^{cd}	- 41%

Each value is the mean ± SD

The values in each column with different superscripts are significantly different at ($p \leq 0.05$).

* The percentage change of the treated groups was calculated compared to the positive control.

** The percentage change of the positive control compared to normal control.

3.5. Effect of the powder and extract of eggplant leaves and peels on antioxidant enzymes (SOD, GPX) and inflammatory marker (CRP) in serum of rats with cisplatin-induced hepatonephrotoxicity.

The results in Table (5) showed the effect of the powder and extract of both leaves and peels of eggplant on two antioxidants enzymes (SOD and GPX) and an inflammation parameter (CRP) in the serum of the rats with hepato-nephrotoxicity induced by cisplatin drug.

Superoxide dismutase (SOD) is an essential enzyme for converting $O2^-$ to H_2O_2, preventing the oxidation caused by superoxide ions. The findings revealed that the serum levels of SOD had decreased significantly in the positive control group (23 ± 1.6 U/ml) compared to the normal control group (48 ± 0.7 U/ml), which reached 52%.

On the other hand, the serum glutathione peroxidase (GPX) levels decreased significantly in the positive group rats (57± 4.6 mU/ml) in comparison with the normal control group (105± 4.5 mU/ml) with a reduction percentage of 45%.

As it is known, glutathione peroxidase is an enzyme responsible for hydrogen peroxide cleavage to water and oxygen molecules (**Ewis and Abdel Rahman, 1995**).

The decline in the two antioxidant enzymes resulted from cisplatin toxicity on the injured rats' liver and kidneys. On the other side, the powder and extract of the leaves and peels of eggplant revealed significant increases in serum SOD and GPX levels in the treated groups compared to the positive control group. The peel extract raised the level of serum SOD to the highest value (43 ± 1.8 U/ml) among the four treated groups with a percentage of 88%, followed by the leaves extract (37 ± 1.9 U/ml) with a percentage of 62%. The same trend was observed in the serum GPX in the groups treated with peel extract and leaf extract, where their values increased significantly compared to the positive control group. Their increase percentages were 75 and 54 %, respectively.

However, the two groups which fed on the powder of peels and leaves showed significant increases in both serum SOD and GPX as

compared to the positive control group, and the peel powder was better than the powder of the leaves in this respect.

Regarding c-reactive protein (CRP), the protein synthesized in the liver, which is associated with body inflammation, the results revealed a significant increase in its level in the blood of the positive control group (2 ± 0.05 mg/L) as compared to the normal control group (1.3 ± 0.03 mg/L) with a percentage of 55%.

The findings showed that all four treated groups led to an improvement in the blood content of CRP, which decreased significantly but didn't reach the level of the normal control group.

The best reduction was observed in the peel extract group, followed by peel powder, where the decrease caused by them reached 25% and 20%, respectively.

In this regard, SOD is one of the enzymes of the antioxidant system that catalyzes the dismutation of superoxide to H_2O_2 in kidney tissues, while catalase catalyzes the decomposition of hydroxyl radicals in the kidney tissues **(Sugumar *et al.* 2016)**. GPx breaks hydrogen peroxide into water and molecular oxygen via the oxidation of reduced glutathione **(Ewis and Abdel Rahman 1995)**. GST is a group of enzymes that catalyze the conjugation of reduced glutathione to a wide range of substrates, usually resulting in detoxification. They also function as transport proteins **(Naik 2010)**.

Sarkar *et al.* (2020) found that the level of SOD in the liver was significantly decreased in the hepatotoxic control group in comparison to the negative control group ($p<0.05$). SMHA (*S. melongena* hydroethanolic extract) at 200 and 400 mg/kg doses significantly elevated the level of SOD in a dose-dependent manner in comparison to the hepatotoxic control group. However, SMHA at 100 mg/kg did not produce any significant difference in SOD enzyme levels. Moreover, the level of SOD in rats receiving SMAQ (*S. melongena* aqueous) (100, 200, and 400 mg/kg) was also found to be improved, which could be attributed to glutathione peroxidase (GPx) activity that decreases H_2O_2 levels, thereby preventing the retroinhibition of

SOD **(Kamaraj *et al.*, 2007)**. Nasunin, an anthocyanin, is predicted to possess strong free radical scavenging activity and protection against lipid and protein oxidation, which have been primarily attributed to its flavonoid fraction **(González-Gallego *et al.*, 2014)**.

In a study, pretreatment with the leaves extract of *S. macrocarpon* at all the three dose levels (250 mg/kg, 500 mg/kg and 750 mg/kg b.w.) resulted in a significant increase ($p<0.05$) in the activities of SOD and prevented the observed peroxidation **(Adewale *et al.* 2015)**. According to **Ekakitie *et al.* (2021),** they found that using different doses of aqueous leaves extract of *S. macrocarpon* increased the activities of superoxide dismutase (SOD) and glutathione peroxidase (GPx) in diabetic rats and compared favorably with the normal control rats. They found that the increases in the activities of superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx) observed in the diabetic rats that received aqueous leave extract of *S. macrocarpon* may be linked to its antioxidant booster. Based on a study by **Elasoru *et al.* (2017)**, significant increases ($p<0.05$) in the hepatic and renal levels of SOD, catalase, and GSH were observed in the rats treated with FRESML (Flavonoid-Rich Extract of *Solanum macrocarpon* Leaves). They suggested that the flavonoid content of the extract was responsible for the ability of the extract to increase the levels of SOD, catalase, and GSH in vivo by reducing reactive free radicals and boost the antioxidant status. **Ekakitie *et al.* (2021)** found that administration of aqueous extract of *Solanum macrocarpon* leaves to diabetic rats demonstrated an increase in the activities of SOD, GPx, GST, and CAT, which showed the ability of this extract to manage oxidative stress in diabetic rats. Generally, the increase in both antioxidant enzymes as well as nonenzymatic biomarkers in rats with liver and kidneys toxicity administered powder and alcoholic extract of *Solanum macrocarpon* leaves and peels is another supporter of their antioxidant potency.

Table 5: Effect of the powder and extract of eggplant leaves and peels on serum SOD, GPX, and CRP levels in rats with cisplatin-induced hepatonephrotoxicity.

Parameters	SOD (U/ml)	Change %*	GPX (mU/ml)	Change %*	CRP (mg/L)	Change %*
Normal control (-ve)	48.47 ± 0.7 [a]		104.67 ± 4.5 [a]		1.28 ± 0.03 [f]	
Positive control (+ve)	23.03 ± 1.6 [f]	- 52%**	57.40 ± 4.6 [e]	- 45%**	1.99 ± 0.05 [a]	+55%**
Leaves powder	32.27 ± 0.9 [e]	+ 40%	71.63 ± 1.9 [d]	+ 25%	1.86 ± 0.03 [b]	-7%
Peels powder	35.07 ± 1.7 [d]	+ 52%	80.67 ± 2.2 [c]	+ 41%	1.61 ± 0.03 [dd]	-19%
Leaves extract	37.40 ± 1.9 [c]	+ 62%	88.57 ± 2.6 [b]	+ 54%	1.72 ± 0.08 [c]	-14%
Peels extract	43.27 ± 1.8 [b]	+ 88%	100.20 ± 2.1[a]	+ 75%	1.48 ± 0.03 [e]	-26%

Each value is the mean ± SD

The values in each column with different superscripts are significantly different at ($p \leq 0.05$).

* The percentage change of the treated groups was calculated compared to the positive control.

** The percentage change of the positive control compared to the normal control.

4. CONCLUSION

The results indicated that the anthocyanin content in the peel extract was higher than that in the leaf extract. A high concentration of polyphenols, particularly anthocyanins, is crucial for the biological functions of both the leaves and peels of eggplant. These components may

serve as preventive and therapeutic agents for healthy individuals as well as for those suffering from liver diseases, especially in cases of hepatotoxicity. The four treated groups exhibited significant reductions in serum levels of ALT, AST, and bilirubin, along with an increase in serum protein levels, with the peel extract showing the most notable effects. The groups that fed on the powder of peels and leaves showed significant decreases in serum creatinine, urea, and uric acid compared to the positive control group. The two groups which fed on the powder of peels and leaves showed significant increases in both serum SOD and GPX as compared to the positive control group, and the peel powder was better than the powder of the leaves in this respect. The findings indicated that all four treatment groups experienced a significant reduction in the blood levels of C-reactive protein (CRP). It is recommended to utilize eggplant leaves and peels as both a preventative and therapeutic agent for healthy individuals as well as those with liver and kidney diseases, particularly for patients dealing with hepatotoxicity and nephrotoxicity.

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تأثير المسحوق والمستخلص الكحولي لأوراق وقشور الباذنجان على السمية المستحثة بواسطة السيسبلاتين في الفئران

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الملخص العربي:

صممت هذه الدراسة لمعرفة تأثير استخدام مسحوق ومستخلص الإيثانول لأوراق وقشور الباذنجان على وظائف الكبد والكلى والإنزيمات المضادة للأكسدة (SOD، GPX) ومستوى بروتين سي التفاعلي (CRP) كما تم إجراء الفحص الكيميائي النباتي لمستخلص الإيثانول الكحولي للأوراق والقشور. بالإضافة إلى ذلك، تم تقدير محتوى المستخلص للأوراق والقشور من المركبات الفينولية والفلافونويد والأنثوسيانين. وفي هذه التجربة تم استخدام ثلاثين فأرا بالغا من الفئران البيضاء، وتم تقسيمهم إلى ست مجموعات (٥ فئران لكل مجموعة)، وتركت واحدة منهم على النظام الغذائي الأساسي وتمت معاملتها كمجموعة ضابطة سالبة وتم حقن المجموعات الأخرى من الفئران بالسيسبلاتين وتمت معاملة إحدى هذه المجموعات كمجموعة ضابطة موجبة وعولجت المجموعات الأربع الأخرى بمسحوق ومستخلصات أوراق وقشور الباذنجان حيث حصلت مجموعتان على المسحوق ومجموعتان على المستخلص وتم ذبح الفئران بعد ٢٨ يوما، وسحب دمائهم للتحليل. أوضحت النتائج أن مستخلص أوراق وقشور الباذنجان يحتوي على مواد فعالة مثل الفلافونويد والتانينات والجليكوزيدات والسابونينات والقلويدات، وأظهرت النتائج أيضا أن محتوى مستخلص الأوراق من مركبات الفينول والفلافونويد أعلى من محتوى مستخلص القشور. على النقيض من ذلك كان محتوى الإنثوسيانين في مستخلص القشور (١٥٠,٩ مجم/ ١٠٠ جرام) أعلى من محتوى مستخلص الأوراق (١٠٧,٦ مجم/ ١٠٠ جرام). وفيما يتعلق بوظائف الكبد والكلى، أظهرت النتائج انخفاضا كبيرا في كل من ALT وAST والبيليروبين BIL وزيادة كبيرة في البروتين الكلي TP في الدم في المجموعات المعالجة بمستخلص القشور والأوراق. كما لوحظ انخفاض في مستوى كرياتينين مصل الدم واليوريا وحمض اليوريك بالمقارنة مع المجموعة الضابطة الموجبة. ومن ناحية أخرى، أدت التغذية على مسحوق ومستخلص أوراق وقشور الباذنجان إلى زيادة في مستوى إنزيم SOD، وإنزيم GPX في الدم في المجموعات المعالجة مقارنة بالمجموعة الضابطة الموجبة وفي الوقت نفسه، أظهرت النتائج أن المجموعات الأربع التي عولجت بمسحوق ومستخلص أوراق وقشور الباذنجان أدت إلى انخفاض ملحوظ في مستوى بروتين سي التفاعلي CRP في الدم، ومن هذه النتائج يتضح أن مستخلص الإيثانول الكحولي للأوراق والقشور كان أكثر فعالية من مسحوق الأوراق والقشور في تقليل السمية الكبدية الكلوية.

الكلمات المفتاحية: السمية الكلوية، السمية الكبدية، السيسبلاتين، الكبد، الكلى، الباذنجان، الانزيمات المضادة للأكسدة

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