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The Effects of Sungkai Leaf and Cinnamon Bark Extracts on MDA and IL-10 in MSG Induced Chronic Kidney Disease in Wistar Rats

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Abstract: Monosodium glutamate (MSG) is known to trigger oxidative stress and inflammation, contributing to kidney tissue damage. This study aimed to evaluate the protective effects of sungkai leaf extract (Peronema canescens Jack) and cinnamon bark extract (Cinnamomum burmannii) on kidney histology, as well as malondialdehyde (MDA) and interleukin-10 (IL-10) levels in male Wistar rats induced with excessive MSG. A total of 30 rats were divided into six groups: normal control, positive control (MSG only), and four treatment groups receiving MSG alongside sungkai leaf extract (28 mg or 56 mg) or cinnamon bark extract (4% or 8%) for 10 days. MDA and IL-10 levels were measured using ELISA, and kidney tissue was examined histologically. The results showed that both extracts significantly reduced MDA (*P*= 0,000) levels and increased IL-10 (*P*= 0,000) levels compared to the positive control. The most prominent protective effect was observed in the group treated with 56 mg of sungkai leaf extract, followed by the 8% cinnamon bark group. Histopathological analysis revealed notable improvements in kidney structure, approaching normal conditions in treated groups. These findings suggest that sungkai leaf and cinnamon bark extracts, particularly at higher doses, offer protective benefits against MSG-induced kidney damage through antioxidant and anti-inflammatory mechanisms.
Keywords: Interleukin-10; kidney; malondialdehyde; monosodium glutamate.

INTRODUCTION

Consumption of commercial or ready-to-eat foods could save time and energy, leading to dietary changes that could negatively impact human health. (Chakraborty, 2019) The production of such foods requires the addition of preservative ingredients to prevent the growth of microorganisms that cause spoilage, thus increasing consumer acceptance. (Chakraborty, 2019; Majewski et al., 2018) Monosodium glutamate (MSG) is one of the most commonly used food additives. (Abd-Elkareem et al., 2022) MSG triggers an increase in *reactive oxygen species* (ROS), altering redox homeostasis and causing systemic damage. (Banerjee et al., 2021) Consumption of MSG has been responsible for a variety of health risks, including nephrotoxicity. Making the search for phytochemical strategies with a broad safety profile to counter MSG toxicity is worthwhile. (Karim et al., 2021)

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The literature differs regarding the safety of MSG as a food additive. While food safety regulators generally consider MSG consumption to be harmless to the human body, based on the fact that MSG does not passively cross cell membranes and is completely metabolized by enterocytes as an energy substrate. Due to the high concentration of polyunsaturated fatty acids in the renal lipid profile, the kidneys are considered an organ with a high susceptibility to free radical attack. Long-term MSG exposure has detrimental effects on the kidneys' health by disrupting redox homeostasis and inducing lipid peroxidation and histological lesions. (Karim et al., 2021) Malondialdehyde (MDA), a product of lipid peroxidation produced when oxidative stress increases, potentially could cause undesirable biological reactions. (Busch & Binder, 2017) Elevated MDA levels indicate a high level of free radical activity and also indicate that cell membranes are undergoing oxidation. (Ayala et al., 2014; Busch & Binder, 2017) Potential tissue damage activates *Interleukin* 10 (IL-10) to reduce the effects of inflammation and infectious conditions. (Verma et al., 2016) IL-10 is a potent anti-inflammatory cytokine, crucial for maintaining immune system homeostasis and preventing chronic inflammatory disorders. (Hutchins et al., 2013)

The chronic stage of kidney disease is characterized by systemic inflammation, oxidative stress, and dysregulated glucose and lipid metabolism. (Tinti et al., 2021) In addition, alterations in the composition of the gut microbiota have been associated with increased levels of uremic toxins in the circulation, thus exacerbating the oxidative and inflammatory burden. (Mafra et al., 2021) The concept of food as medicine (nutrients and bioactive compounds obtained from food) has gained traction and been used to improve health. (Mafra et al., 2021) Among such, cinnamon bark and leaves Sungkai's medicinal properties have shown various benefits of include the potential to control inflammation, oxidative stress, and intestinal dysbiosis. (Mohsin et al., 2023; Okfrianti et al., 2022; Ramadhani et al., 2022; Rao & Gan, 2014)

Interest is growing in the use of natural ingredients in medicine for such purposes. (Husni, J, et al., 2023) Herbal medicines are becoming increasingly popular among patients due to their favorable shown to cause no serious side effects. (Salm et al., 2023), Sungkai (*Peronema canescens* Jack) and cinnamon (*Cinnamomum burmannii*) have attracted interest due to their rich bioactive compounds and potential health benefits. Sungkai leaves contain flavonoids, alkaloids, steroids, phenolics, tannins, and saponins, which exhibit antioxidant, antibacterial, and immunostimulatory properties. Previous studies also reported that oral administration of sungkai extract in animal models was non-toxic, suggesting its safety for therapeutic use (HelmyAbdou et al., 2019; Husni, Yunedi, et al., 2023). Cinnamon bark is abundant in catechin, epicatechin, procyanidin B2, quercitrin, and cinnamic acid, known for strong antioxidant and anti-inflammatory activities (Rahayu et al., 2022). Cinnamon extracts have been shown to reduce oxidative stress markers, modulate pro-inflammatory cytokines, and improve tissue recovery. (HelmyAbdou et al., 2019) These properties make sungkai and cinnamon promising candidates for mitigating oxidative stress and inflammation, including conditions such as MSG induced kidney damage.

In line with these findings, a study using methanol extract of Indonesian cinnamon from Kerinci, Sumatra, revealed the presence of catechin, epicatechin, procyanidin B2, quercitrin, 3,4-dihydroxybenzaldehyde, protocatechuic acid, and cinnamic acid through ultrasonic extraction. (Rahayu et al., 2022) Cinnamon peel extract demonstrated a significant restorative effect on hepatotoxicity changes induced by exposure to multi-walled carbon nanotubes (MWCNTs).

The use of natural ingredients could be a relevant alternative to reduce foodborne toxins. (Banerjee et al., 2021) High free radical content can be reduced with

antioxidant compounds. Antioxidants are compounds that have the ability to release hydrogen to reduce free radical levels. (Kayode et al., 2020) Based on these antioxidant mechanisms, sungkai leaf extract and cinnamon bark can be used as natural antioxidants capable of neutralizing ROS and thus repairing cell damage.

Previous studies on *Peronema canescens* (sungkai) have mainly focused on its phytochemical composition and systemic effects. For example, Pratiwi et al. (2021) reported that sungkai leaf extracts exhibit strong anti-cholesterol activity, particularly in the ethyl acetate fraction. (Dillasamola et al., 2021) further highlighted its immunostimulatory potential through enhanced macrophage phagocytosis and cytokine regulation in vivo and in vitro. While these findings confirm the biological activity and safety of sungkai, none have evaluated its role in protecting against organ-specific oxidative damage.

Similarly, cinnamon (*Cinnamomum burmannii*) has been widely investigated for its antioxidant, anti-inflammatory, and metabolic benefits, including hepatoprotective effects against chemical injury (HelmyAbdou et al., 2019; Rahayu et al., 2022). However, its effect in the context of MSG-induced renal toxicity remains underexplored. Therefore, there are still few reports on the effects of sungkai leaf extract and cinnamon bark on kidney histology as well as Malondialdehyde (MDA) and interleukin 10 (IL-10) levels in mice induced with excessive Monosodium Glutamate (MSG); further study is warranted.

This study, therefore, tries to evaluate Malondialdehyde (MDA) and interleukin 10 (IL-10) potential as natural antioxidants and anti-inflammatory agents for renal protection.

MATERIALS AND METHODS

This research was designed as a true experimental laboratory study using a post-test only control group design to assess the effects of Sungkai (*Paronema canescens*) leaf and cinnamon bark (*Cinnamomum burmanii*) extract on the relation to kidney damage in rats induced with monosodium glutamate (MSG). The study model employed male Wistar rats (*Rattus norvegicus*), aged three to four months and weighing between 200–250 grams.

Six groups of rats were used in the study, with animals randomly distributed among six groups following inclusion criteria to ensure uniformity across groups, Each experimental group consisted of five rats, and the number of animals was determined according to the World Health Organization's guidelines for animal studies.(G.V. Asokan et al., 2012) Inclusion criteria included healthy male Wistar rats, male Wistar rats is choice to avoid the influence of female hormonal cycles, which can affect kidney function, oxidative stress, and cytokine levels. Male rats are also more commonly used in kidney damage studies, making it easier to compare our results with previous research. In addition, males tend to show stronger oxidative stress responses, which makes it easier to observe the protective effects of the extracts.(Lima-Posada et al., 2017; Lima-Posada & Bobadilla, 2021; Ma et al., 2021) The rats included in this study are within the criteria of the specified age and weight range, while exclusion criteria involved anatomical abnormalities, signs of illness, weight outside the desired range, or mortality during the study. During the study, no animals died or developed infections; therefore, all rats were included in the final analysis. The groups consisted of a healthy control group with no intervention, a positive control group induced with MSG without further treatment, and four treatment groups receiving various doses of *Sungkai* leaf or cinnamon bark extract after MSG induction. Rats were first acclimatized for seven days, maintained under standard laboratory conditions with

sufficient food and water, and housed at ambient room temperatures with proper ventilation.

After the acclimation period ended, Rats in the treatment groups received oral administration of Sungkai leaf extract or cinnamon bark extract via gavage once daily for 10 days, depending on each treatment. Sungkai leaf (*Peronema canescens* Jack) was obtained from Jambi Province, Indonesia, where the plant grows abundantly. Fresh sungkai leaves were dried, powdered (1,000 g), and placed in a dark container. The powder was macerated with 70% ethanol for five days with occasional shaking, then filtered through flannel cloth. The residue was washed with solvent until the filtrate volume reached 750 mL. The combined filtrates were concentrated using a vacuum evaporator to yield a viscous extract. Dosages were calculated by body weight conversion, corresponding to 40 mg/rat/day (≈200 mg/kgBW) and 80 mg/rat/day (≈400 mg/kgBW). The required dose was weighed, dissolved in 2 mL of distilled water, and given by oral gavage. While cinnamon bark extract (*Cinnamomum burmannii*) was prepared from dried bark (1 kg) cleaned and oven-dried at 40 °C until water content was <10%. The dried bark was sorted, cut, ground into powder, and sieved (20 mesh). About 450 g of powder was macerated in 1,500 mL of 70% ethanol in dark containers. After extraction, the filtrate was processed into a thick extract. From this, oral suspensions were prepared at 4% (4.0 g extract per 100 mL) and 8% (8.0 g extract per 100 mL) using CMC-Na as a suspending agent. Each rat received 2 mL/day of the prepared suspension by oral gavage. A dose of 1 gram MSG diluted in 2 mL distilled water was administered to induce renal stress prior to treatment.

At the end of the treatment period, blood samples were collected from each rat via the orbital sinus to measure serum levels of malondialdehyde (MDA) and interleukin-10 (IL-10). Additionally, histopathological examination of kidney tissues was conducted using hematoxylin-eosin (HE) staining to assess structural changes.

All procedures and sample analyses were conducted at the Integrated Biomedical Laboratory, Faculty of Medicine, Sultan Agung Islamic University, Semarang. The research period spanned from June 17 to July 25, 2025, covering animal adaptation, treatment administration, and data collection. While procedures were approved by the Ethics Committee of the Faculty of Medicine, Sultan Agung Islamic University, Semarang, with No 308/VI/2025/Bioethics Commission.

Data on MDA levels were obtained through spectrophotometric analysis using the thiobarbituric acid (TBA) method, while IL-10 levels were assessed using the enzyme-linked *immunosorbent assay* (ELISA) technique. All laboratory work utilized standard equipment for biochemical and histological analysis, including centrifuges, ELISA readers, spectrophotometers, micropipettes, and other basic glassware.

Measurement of Malondialdehyde (MDA) Levels Using the TBARS Method

On the 18th day of the experiment, measurement of malondialdehyde (MDA) levels was performed on each treatment group following the administration of sungkai (*Paronema canescens*) leaf extract. The MDA concentration was determined using the Thiobarbituric Acid Reactive Substances (TBARS) assay before Blood samples were collected from the retro-orbital sinus of each rat using a capillary tube, with 1 mL of blood transferred into a centrifuge tube. The blood samples were centrifuged at 3,000 rpm for 30 minutes to separate the serum. A volume of 500 µL of the resulting supernatant was transferred into a new centrifuge tube and mixed with 500 µL of 20% trichloroacetic acid (TCA), followed by the addition of 1% thiobarbituric acid (TBA) dissolved in glacial acetic acid (CH_3COOH) at a 50% concentration.

The mixture was incubated in a water bath at 95°C for 45 minutes, then cooled to room temperature. Subsequently, the samples were centrifuged again at 3,000 rpm

for 30 minutes. From the resulting solution, 500 µL of the clear filtrate was collected using a micropipette. The absorbance of the filtrate was measured at a wavelength of 532 nm using a UV-Vis spectrophotometer to determine the MDA concentration, which reflects lipid peroxidation levels in the samples.

Measurement of Interleukin-10 (IL-10) Levels Using the ELISA Method

On the 18th day of the study, measurement of IL-10 levels was conducted following the administration of sungkai (*Paronema canescens*) leaf extract in each respective group. The IL-10 concentration was determined using the Enzyme-Linked Immunosorbent Assay (ELISA) method, following standardized procedures. Prior to testing, all reagents, including standard solutions and samples, were equilibrated to room temperature. The number of *ELISA* strip wells required was calculated in advance; any unused strips were stored in a sealed aluminum zip bag at 2–8°C for future use.

To begin the assay, 50 µL of IL-10 standard solution was added to each designated standard well. Notably, no antibody was added to the standard wells as the standard solution already contained biotin-labeled antibody. For the sample wells, 40 µL of serum sample was pipetted, followed by the addition of 10 µL of IL-10 antibody to the same wells. Subsequently, 50 µL of streptavidin-HRP conjugate was added to both the sample and standard wells. The plate was then sealed and incubated at 37°C for 60 minutes.

After incubation, the plate was unsealed and washed five times using a wash buffer, with each wash consisting of at least 0.3 mL per well for 30 seconds to 1 minute. Next, 50 µL of Substrate A was added to each well, followed by 50 µL of Substrate B. The plate was sealed again and incubated in the dark at 37°C for 10 minutes. Finally, 50 µL of Stop Solution was added to each well, resulting in an immediate color change from blue to yellow.

The optical density (OD) of each well was measured within 10 minutes of adding the Stop Solution using a microplate reader set to a wavelength of 450 nm. This OD value was used to calculate the concentration of IL-10 in each sample.

Statistical Analysis

The data obtained from this study were analyzed using a stepwise statistical approach. First, normality of distribution was assessed using the Shapiro-Wilk test, while data homogeneity was evaluated using Levene's test. A significance level of $p > 0.05$ indicated that the data were normally distributed and homogeneous. Then, differences between groups were analyzed using *one-way Analysis of Variance* (ANOVA), followed by the *Least Significant Difference* (LSD) post hoc test to determine statistically significant differences between specific treatment groups ($p < 0.05$).

This statistical approach ensured robust interpretation of experimental outcomes, allowing appropriate analysis according to the characteristics of the dataset. All tests were performed with a 95% confidence interval, and significance was determined at $p < 0.05$.

RESULTS AND DISCUSSION

Histological Features of Kidney Tissue in Each Group Using Hematoxylin-Eosin (HE) Staining

Histological observations of kidney tissues from each group were conducted using Hematoxylin-Eosin (HE) staining to evaluate morphological alterations resulting from monosodium glutamate (MSG) induction and the therapeutic effects of sungkai leaf (*Paronema canescens)* extract and cinnamon bark (*Cinnamomum burmannii)*

extract. HE staining allowed clear visualization of cellular structures, with hematoxylin staining cell nuclei purplish-blue and eosin staining cytoplasm and extracellular matrix pink. This histopathological analysis aimed to assess renal damage, such as congestion, degeneration, necrosis, and structural repair, which reflect responses to oxidative stress and inflammation.

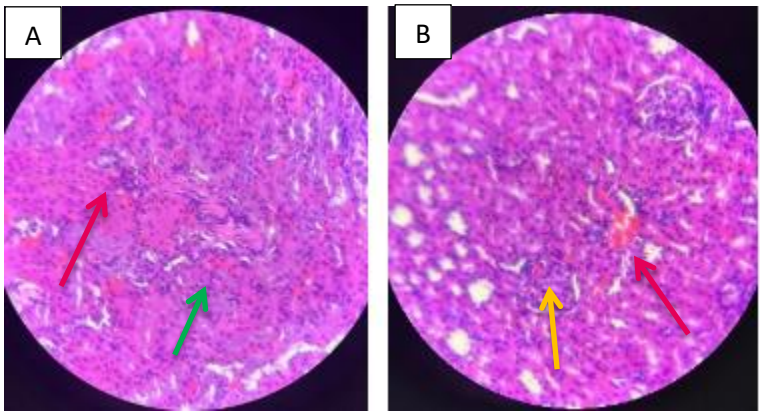

Figure 1. Histology of kidney tissue in the healthy rat group (A) and MSG-induced positive control group (B).

Comparison of kidney histology (Figure 1) between the healthy control group and the positive control group revealed significant structural alterations induced by MSG. The healthy group displayed intact nephron architecture, compact glomeruli (red arrow), and well-organized tubules without evidence of vacuolization, congestion, or inflammatory infiltration (green arrow). In contrast, the positive control group exhibited tubular degeneration, luminal dilatation, cytoplasmic vacuolization (orange arrow), congestion, and infiltration of inflammatory cells in the interstitial space (red arrow), indicating structural kidney damage caused by oxidative stress and inflammation triggered by MSG.

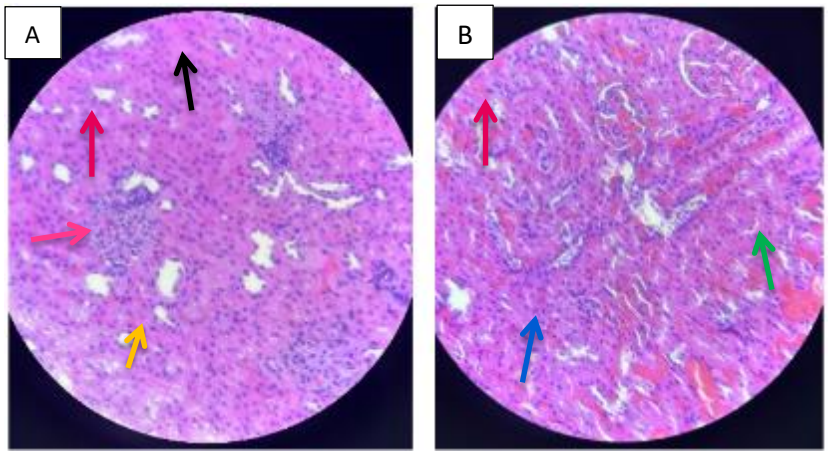

Figure 2. Histology of kidney tissue in Treatment Group 1 with 28 mg/rat sungkai leaf extract (A) and Treatment Group 2 with 56 mg/rat sungkai leaf extract (B).

Histological observations (Figure 2) in Treatment Group 1 (28 mg/kg Sungkai leaf extract in rats) showed persistent vacuolization (red arrow) and tubular damage (black arrow), accompanied by interstitial alterations (pink arrow) and mild inflammatory infiltration (orange arrow). The glomeruli were poorly defined. In contrast, Treatment Group 2 (56 mg/kg Sungkai leaf extract in rats) demonstrated better

structural recovery, with organized tubules, reduced vacuolization (red arrow), and minimal inflammatory infiltration (blue arrow). The glomerular morphology appeared nearly normal (green arrow), indicating a dose-dependent protective effect.

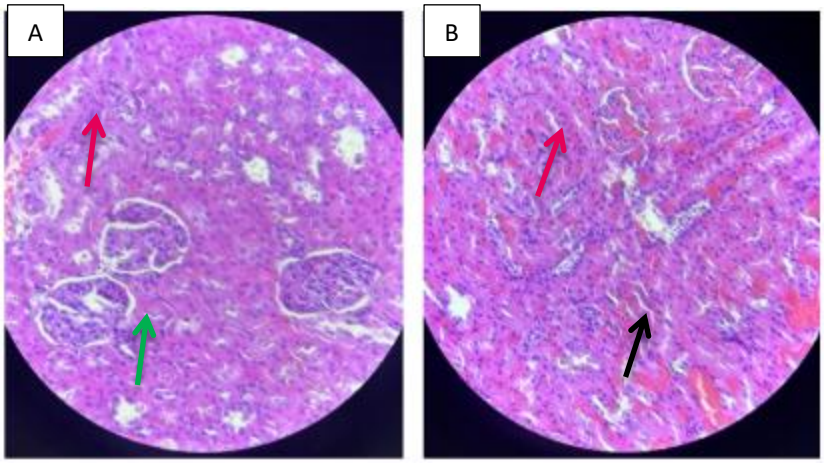

Figure 3. Histology of kidney tissue in Treatment Group 3 with 4% cinnamon extract (A) and Treatment Group 4 with 8% cinnamon extract (B).

Histological analysis (Figure 3) of Treatment Group 3 (4% cinnamon extract) showed mild vacuolization (red arrow) and partially restored tubular structures (green arrow), with clearly defined glomeruli. Meanwhile, Treatment Group 4 (8% cinnamon extract) demonstrated optimal histological recovery, with almost no vacuolization (red arrow), well-organized tubules (black arrow), and intact glomeruli. These observations indicate superior protective efficacy at the higher concentration of cinnamon extract.

The MSG-induced kidney damage seen in this study, including tubular degeneration, lumen dilation, vacuolization, congestion, and inflammatory infiltration, is consistent with existing literature. Chronic MSG intake has been shown to cause oxidative renal injury (Sharma, 2015), and histomorphometry studies report Bowman's space enlargement, glomerular distortion, and mesangial proliferation in MSG-exposed rats (Dixit et al., 2014).

Sungkai leaf extract provided dose-dependent protection, improving tubule organization and glomerular morphology. Previous studies have identified immunomodulatory and anti-inflammatory properties in *P. canescens*, including IL-6 inhibition and preserved lymphocyte counts (Rahardhian et al., 2025), and reduced TNF-α in ARDS (Maigoda et al., 2023), supporting its protective effect.

Cinnamon bark extract also offered strong histological recovery, especially at 8% concentration. Cinnamon is well-documented for its antioxidant potential in managing kidney complications and chronic disease (Moreira et al., 2023). Its essential oil has been shown to mitigate oxidative kidney damage, and its phenolic content (polyphenols, cinnamaldehyde) is known to reduce oxidative stress biomarkers and improve renal function by lowering urea levels. (Moreira et al., 2023)

These comparisons underscore that both sungkai and cinnamon extracts can counteract MSG-induced renal damage, with sungkai offering immunomodulation and cinnamon providing antioxidant-driven structural protection. The novelty of this study lies in directly comparing these two extracts under MSG-induced nephrotoxic conditions.

Analysis of MDA Levels in Kidney Tissue Across Treatment Groups

Analysis of malondialdehyde (MDA) levels was performed to evaluate the extent of oxidative damage in rat kidney tissues following toxic compound induction

and to assess the therapeutic effects of various plant extracts. MDA levels were measured in all groups—including normal control, positive control, and treatment groups—to provide a comparative overview of oxidative stress across conditions. The results are presented as mean ± standard deviation and were statistically analyzed to determine significant differences among groups (Table 1).

Table 1. Mean MDA Levels (ng/mL) and One-Way ANOVA Results

Groups	MDA Levels (ng/mL)						
	KN	KP	K1	K2	K3	K4	P value
Mean	1.98	3.84	2.55	1.65	2.77	1.73	
SD	0.24	0.64	0.45	0.51	0.59	0.58	
Shapiro-Wilk	0.362	0.959	0.821	0.352	0.793	0.926	
Leuvene Test							0.770
One way anova							0.000

Note: Shapiro-Wilk = normal distribution ($p > 0.05$)
Levene's test = homogeneous variance ($p > 0.05$)
ANOVA = significant ($p < 0.05$)

The highest mean MDA level was observed in the positive control group (KP), at 3.84 ± 0.64 ng/mL, indicating elevated lipid peroxidation due to oxidative stress. Conversely, the normal control group (KN), which received no induction or treatment, showed the lowest MDA level at 1.98 ± 0.24 ng/mL, reflecting a physiological state with minimal oxidative disruption.

Treatment group 1 (K1), which received 28 mg/rat of sungkai leaf (*Paronema canescens)* sun extract, showed a moderate decrease in MDA level to 2.55 ± 0.45 ng/mL. Treatment group 2 (K2), which received a higher dose of 56 mg/rat, showed a more pronounced reduction to 1.65 ± 0.51 ng/mL. This dose-dependent decrease suggests that higher concentrations of sungkai extract enhance its antioxidant efficacy.

Similarly, cinnamon bark extract treatment group 3 (K3, 4% concentration) resulted in an MDA level of 2.77 ± 0.59 ng/mL, whereas treatment group 4 (K4, 8% concentration) showed a significant reduction to 1.73 ± 0.58 ng/mL. These results demonstrate the antioxidant potential of both herbal extracts at higher concentrations. These outcomes reflect the presence of potent antioxidative compounds in cinnamon, such as cinnamaldehyde, polyphenols, and flavonoids, which are known to scavenge free radicals and inhibit lipid peroxidation leading to more effective mitigation of oxidative stress. (Ahkam et al., 2024)

Normality and homogeneity testing using the Shapiro-Wilk and Levene's tests indicated that the data were normally distributed and had homogeneous variance ($p > 0.05$). One-way ANOVA revealed a statistically significant difference among groups ($p = 0.000$), confirming that the treatments significantly affected MDA levels. Both sungkai leaf and cinnamon bark extracts significantly reduced MDA concentrations, with the most effective results observed in group K2 (sungkai 56 mg) and group K4 (cinnamon 8%).

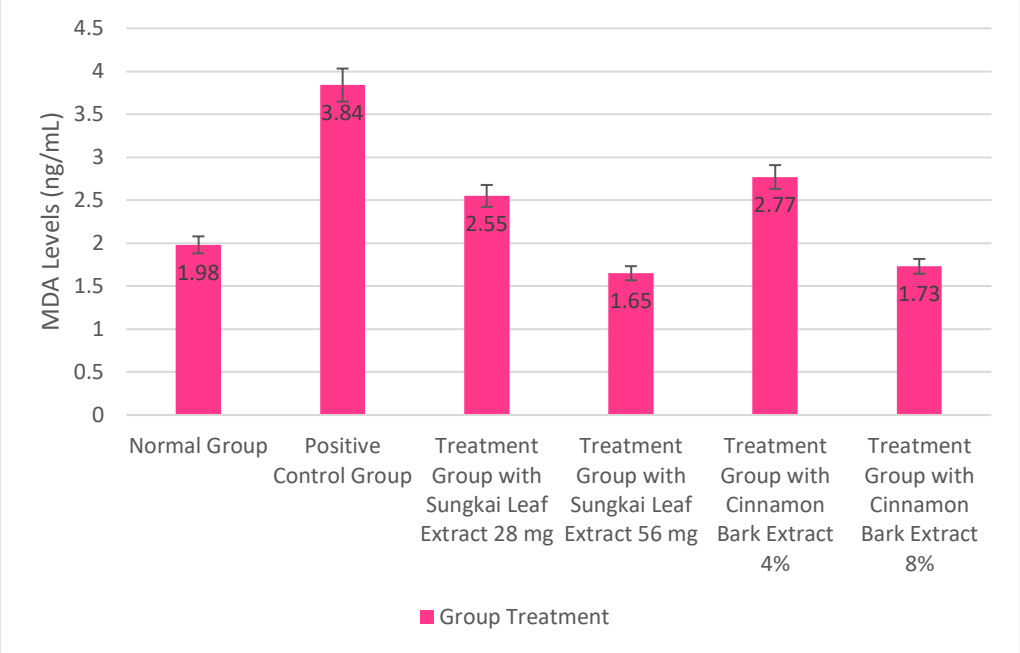

Figure 4. Mean MDA Levels (ng/mL) in Each Treatment Group

Table 2. LSD Post Hoc Test Results for MDA Levels Between Groups

Comperation group	KN	KP	K1	K2	K3	K4
KN	-	0.000	0.094	0.323	0.023	0.456
KP	-	-	0.001	0.000	0.003	0.000
K1	-	-	-	0.011	0.500	0.020
K2	-	-	-	-	0.002	0.804
K3	-	-	-	-	-	0.004

Post hoc LSD analysis revealed significant differences between the positive control group (KP) and all other groups, including KN (p = 0.000), K1 (p = 0.001), K2 (p = 0.000), K3 (p = 0.003), and K4 (p = 0.000). This highlights the severity of oxidative stress induced by MSG and the relative protective effects of the administered treatments.

Comparisons between KN and the treatment groups revealed a significant difference only with Group K3 (p = 0.023), while K1 (p = 0.094), K2 (p = 0.323), and K4 (p = 0.456) showed no significant differences—suggesting those treatments were effective in restoring MDA levels to near-normal.

Group K1 differed significantly from K2 (p = 0.011) and K4 (p = 0.020), but not from K3 (p = 0.500). Group K2 differed significantly from K3 (p = 0.002), but not from K4 (p = 0.804), suggesting that higher doses of both extracts yield more substantial antioxidant effects. Furthermore, K3 significantly differed from K4 (p = 0.004), indicating greater efficacy of 8% cinnamon extract compared to 4%.

In conclusion, both the 56 mg/rat dose of sungkai leaf extract and the 8% cinnamon extract exhibited strong protective effects against oxidative stress, as demonstrated by significantly reduced MDA levels compared to both the positive control and lower-dose treatment groups.

Analysis of IL-10 Expression in Rat Kidney Tissue Across Treatment Groups

The analysis of IL-10 levels in rat kidney tissue across treatment groups is summarized in Table 3. and illustrated in Figure 5.

Table 3. Descriptive Mean of IL-10 Levels (pg/mL) and One-Way ANOVA Results

Group	IL-10 Levels (pg/mL)						
	KN	KP	K1	K2	K3	K4	P value
Mean	165.68	75.55	104.12	184.13	108.90	131.30	
SD	26.17	16.04	14.40	42.85	21.42	27.10	
Shapiro-Wilk	0.871	0.486	0.620	0.886	0.485	0.639	
Leuvene Test							0.077
One way anova							0.000

Note: Shapiro-Wilk = normal distribution ($p > 0.05$)
Levene Test = homogeneous ($p > 0.05$)
One-Way ANOVA = significant ($p < 0.05$)

Based on Table 3 and Figure 5, the highest mean IL-10 level was observed in the normal group (KN), reaching 165.68 ± 26.17 pg/mL. In contrast, the lowest IL-10 level was found in the positive control group (KP), which received toxic induction without any treatment, showing 75.55 ± 16.04 pg/mL.

Treatment with 28 mg of Sungkai leaf extract (K1) resulted in an IL-10 level of 104.12 ± 14.40 pg/mL, which was an improvement compared to KP, though still below the normal level. Remarkably, the 56 mg dose of *Sungkai* leaf extract (K2) induced the highest IL-10 expression across all groups at 184.13 ± 42.85 pg/mL, surpassing even the normal group, indicating a strong anti-inflammatory response to oxidative stress.

The groups treated with cinnamon bark extract showed a dose-dependent effect as well. The 4% concentration (K3) yielded an IL-10 level of 108.90 ± 21.42 pg/mL, while the 8% concentration (K4) increased IL-10 to 131.30 ± 27.10 pg/mL. Although both treatments enhanced IL-10 levels compared to the positive control, the effect was less pronounced than that of the high-dose *Sungkai* extract.

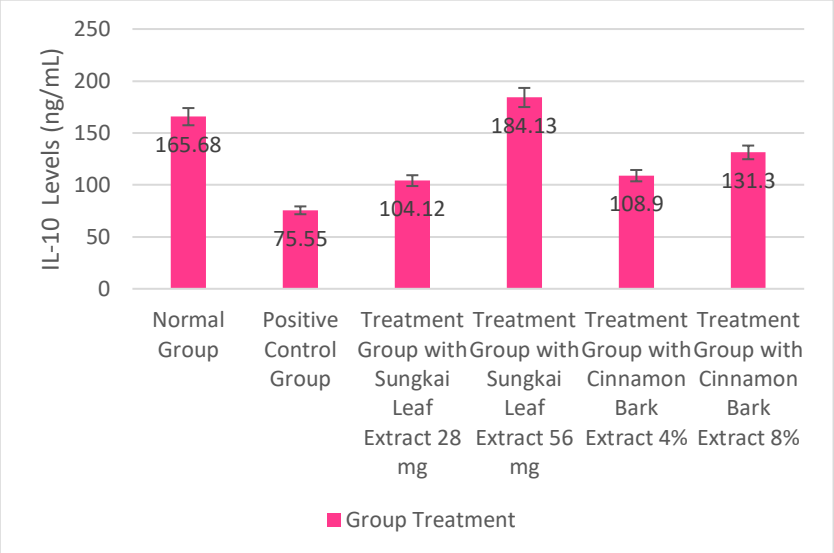

Figure 5. Mean IL-10 Levels (pg/mL) in Each Experimental Group

Statistical tests confirmed the normal distribution of the data (Shapiro-Wilk p > 0.05) and homogeneity across groups (Levene Test p = 0.077). One-way ANOVA revealed a statistically significant difference in IL-10 levels between the groups (p = 0.000), indicating that the treatments had a measurable effect on anti-inflammatory response.

Table 4. LSD Post Hoc Test for IL-10 Levels Among Treatment Groups

Comparation Group	KN	KP	K1	K2	K3	K4
KN	-	0.000	0.001	0.280	0.002	0.050
KP	-	-	0.100	0.000	0.057	0.003
K1	-	-	-	0.000	0.778	0.117
K2	-	-	-	-	0.000	0.004
K3	-	-	-	-	-	0.192

Note: * indicates statistically significant difference (p < 0.05)

LSD post hoc analysis revealed that the positive control group (KP) was significantly different from most other groups, particularly K2 and K4, confirming the effectiveness of both treatments in upregulating IL-10. Notably, group K2 (Sungkai extract 56 mg) consistently showed the highest anti-inflammatory effect, statistically indistinguishable from the normal group. Cinnamon bark extract at 8% (K4) also produced a significant elevation of IL-10, though to a lesser extent.

These findings suggest that both Sungkai leaf and cinnamon bark extracts exhibit notable anti-inflammatory effects in renal tissue, with higher doses offering more substantial benefits. The pronounced IL-10 increase in K2 underscores the therapeutic potential of Sungkai in mitigating inflammation-induced oxidative damage in kidney tissue.

This study has several limitations that should be considered when interpreting the findings and in planning future research. First, the use of male Wistar rats as an in vivo model provides valuable insight into the biological response to MSG induction, but cannot fully capture the complexity of human physiology, particularly in the context of chronic kidney disease. While animal models are useful for mechanistic understanding, their translational value to human clinical outcomes remains limited.

Second, the relatively short treatment duration (18 days) may not be sufficient to evaluate the long-term effects of *Peronema canescens* (sungkai) leaf extract and *Cinnamomum burmannii* (cinnamon) bark extract, either in terms of histopathological recovery or broader molecular biomarkers of oxidative stress and inflammation. Cumulative effects and potential long-term toxicity were also not assessed in this study.

Finally, this study evaluated only two biochemical parameters—MDA as a marker of oxidative stress and IL-10 as a marker of anti-inflammatory response. However, nephropathy induced by oxidative stress and inflammation involves multiple molecular pathways, including antioxidant gene expression (e.g., SOD, GPx), additional cytokines (TNF-α, IL-6), and growth factors (TGF-β), which were not explored here (Sies et al., 2017).

CONCLUSION

The administration of Sungkai (*Peronema canescens* Jack) leaf extract and cinnamon (*Cinnamomum burmannii*) bark extract was effective in reducing oxidative

stress and increasing IL-10 levels in rat kidney tissue induced with monosodium glutamate. The most significant protective effects were observed in the group treated with Sungkai leaf extract at 56 mg and cinnamon bark extract at 8%, indicating their potential as anti-inflammatory and antioxidant agents in renal tissue recovery. Further studies are recommended to explore the long-term effects and mechanisms of these herbal extracts at the molecular level, including their influence on other inflammatory mediators and tissue regeneration. Testing on different models or clinical trials may also provide insights into potential therapeutic applications in humans.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the content or publication of this manuscript.

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