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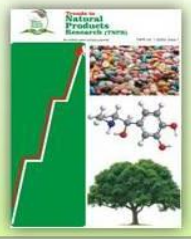

Effect of *Zea mays* L. (Poaceae) starch slurry on the histopathological and biochemical changes in ethanol-induced ulcer and water immersion restrain stress-induced ulcer models in rats

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Keywords: superoxide dismutase, malondialdehyde, *Zea mays*, ethanol-induced ulcer

Abstract: In this work, we further explored on our earlier findings by investigating the effect of *Zea mays* L. (Poaceae) starch slurry on histopathological and biochemical changes in ethanol-induced ulcer (EIU) and water immersion restrain stress-induced ulcer (WIRSIU) models in rat. The levels of superoxide dismutase (SOD) and malondialdehyde (MDA) levels were also investigated in EIU and WIRSIU models in rats. In the EIU model, *Zea mays* starch slurry (ZM) increased the gastric SOD levels compared to the negative control group. The increase in SOD levels was significant ($p < 0.001$) and dose-dependent with the 5000 mg/kg eliciting the highest response (8.20 ± 0.25). When compared to the standard treatment, the 5000 mg/kg elicited a higher response. On the other hand, ZM produced decreased levels of MDA in EIU model in a dose-dependent manner (0.66 ± 0.17). In WIRSIU model, ZM also increased the SOD levels compared to the negative control group. The increase in SOD levels was significant ($p < 0.05$) and dose-dependent with the 5000 mg/kg eliciting the best response (3.13 ± 0.28). When compared to the standard treatment, the 5000 mg/kg elicited a somewhat similar response. Also, ZM produced decreased levels of MDA in WIRSIU which was also dose-dependent (1.20 ± 0.06). Upon histopathological examinations in both EIU and WIRSIU models, 5000 mg/kg of ZM showed a mild necrosis of the mucosal structures. The level of necrosis was dose-dependent with a higher dose showing a lesser necrosis and vice versa. Thus, from the present investigation, it can be concluded that *Zea mays* starch slurry afforded significant antiulcer activity by enhancing antioxidant potential of the gastric mucosa, thereby reducing mucosal damage.

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INTRODUCTION

Histopathology is the microscopic (histological) examination of tissues. Histopathology is the diagnosis and study of diseases of the tissues, and involves examining tissues and/or cells under a microscope (The Royal College of Pathologists, 2023). In ulcer conditions, the histopathological appearance of the mucosal structures is damaged. Active ulcers have four histopathological prototypical zones; (1) surface neutrophils, bacteria, and necrotic debris (2) fibrinoid necrosis at the base and margins (3) granulation tissue with chronic inflammatory cells (4) fibrous or collagenous scars in muscularis propria with thickened blood vessels showing endarteritis obliterans (Weisenberg, 2012). Here, the surface is covered with slough and inflammatory debris. Beneath this neutrophilic infiltration, active granulation with mononuclear leukocytic infiltration and fibrinoid necrosis may be seen (Anand, 2019). In chronic superficial gastritis, lymphocytes, monocytes, and plasma cells often infiltrate the mucosa and sub mucosa (Weisenberg, 2012).

Furthermore, biochemical changes are also observed in ulcer conditions. Oxidizing agents such as reactive oxygen species (ROS) are generated through numerous normal metabolic processes and are needed for normal functioning of the organism (Juan *et al*., 2021). Various antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPX) control their accumulation (Zheng *et al*., 2023). Any imbalance in the activity of these enzymes normally leads to faulty disposal of free radicals and its accumulation. These ROS are responsible for oxidation of tissues leading to lipid peroxidation and tissue damage (Bhatti *et al*., 2022). They are also responsible for oxidation of bases in cellular deoxyribonucleic acid (DNA) making them mutagenic, cytotoxic and crosslinking agents, which in turn causes uncontrolled expression of certain genes causing increased multiplication of cells leading to cancer (Bhatti *et al*., 2022). Antioxidants seemed to have protective role in gastric ulcers and carcinomas (Tandon *et al*., 2004). Preventive antioxidants, such as superoxide dismutase (SOD) and catalase (CAT) enzymes are the first line of defense against reactive oxygen species (Nguyen *et al*., 2020). Reduced glutathione (GSH), SOD and CAT are vital endogenous antioxidants which protect bio membrane from oxidative damage by scavenging ROS (Wu *et al*., 2022). Furthermore, SOD, an intracellular enzymatic antioxidant, mainly converts harmful oxygen radicals into less dangerous hydrogen peroxide (H_2O_2) and further metabolizes H_2O_2 into safe water (Islam *et al*., 2022). Also, CAT can scavenge ROS by triggering the rapid conversion of peroxyl radical (H_2O^{2-}) into water and oxygen. On the other hand, malondialdehyde (MDA) is a metabolite for oxidative stress which is generated by unsaturated fatty acids through ROS-activated lipid peroxidation (Cordiano *et al*., 2023). In the mucosa, GSH is considered as an anti-oxidative barrier which protects the gastric mucosa against oxidative stress caused by free radicals and peroxides. It also coordinates with some other antioxidant enzymes then alleviates oxidative damage. Thus, MDA is deemed as the biomarker of lipid peroxidation and used to quantify and identify oxidative stress (Xue *et al*., 2018). Reduced glutathione (GSH) is a major low molecular weight scavenger of free radicals in the cytoplasm and an important inhibitor of free radical mediated lipid peroxidation (Wu *et al*., 2022). Lipid peroxidation is a free radical mediated process, which has been implicated in a variety of disease states (Xue *et al*., 2018). It involves the formation and propagation of lipid radicals, the uptake of oxygen and rearrangement of double bonds in unsaturated lipids which eventually results in destruction of membrane lipids (Xue *et al*., 2018). It is therefore imperative to ensure protection of the mucosal structures and activation of antioxidant enzyme systems to minimize ulcer conditions.

Medicinal plants containing active phyto-constituents have been proven as useful source in the prevention and treatment of various diseases including gastrointestinal problems (Sabira *et al*., 2014; Vimala and Shoba, 2014). The prevalence of peptic ulcer disease has shifted from predominance in males to similar occurrence in males and females. The lifetime prevalence is approximately 11%-14% in men and 8-11% in women (Charisius, 2014). In view of this, there is therefore the need to screen for natural agents with better safety and efficacy profile to manage ulcer.

Maize starch (*Zea mays L*) has been identified for its several medicinal properties (Kumar and Jhariya, 2013; Jadhav, 2016). Maize starch is a commonly used adjuvants in medication production. Isiogugu and colleagues successfully demonstrated the anti-ulcer property of maize (Isiogugu *et al*., 2020). In this work, we further explored on our earlier findings by investigating the effect of *Zea mays* L. (Poaceae) starch slurry on histopathological and biochemical changes in ethanol-induced ulcer and water immersion restrain stress-induced ulcer in rats. Findings from this study might serve as a step in developing natural remedies for ulcers and data gathered from these experiments will also go a long way in helping medication production companies allocate an informed standard of choice in sourcing maize starch and by extension help reduce side effects occurrence as seen with most synthetic ulcer medications. The use of maize starch will reduce the overhead cost incurred from importing potential adjuvants, as maize starch can be locally sourced and by extension increase medication accessibility, and treatment course adherence.

MATERIALS AND METHODS

Adult Swiss albino rats (100-120 g) and mice (20-25 g) of either sex bred in the Laboratory Animal Facility of the Department of Pharmacology and Toxicology, Faculty of Pharmaceutical Sciences, University of Nigeria, Nsukka (UNN) were used. The experimental protocols were approved by the University Ethics Committee with a certification number (DPTFPSUNN423). All animal experiment were in compliance with the principles for laboratory animal use and care of the National Institute of Health Guide for Care and Use of Laboratory Animals (NIH publication #85-23, revised in 1985)

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Plant collection, authentication and preparation

The grains of *Zea mays* were collected from the botanical garden of the Faculty of Agricultural Sciences, University of Nigeria, Nsukka in July 2019 and authenticated by Mr Alfred Ozioko of the International Centre for Ethnomedicines and Drug Development (INTERCEDD) Nsukka, Enugu State, where a voucher specimen was deposited (specimen number: INTERCEDD 1576). The grains were prepared according to the process highlighted by Isiogugu and colleagues (Isiogugu *et* al., 2020). The plant name was checked with http://www.theplantlist.org/ on February 5. 2020.

Ethanol-induced ulcer (EIU) model

Ethanol-induced ulcer in rats was evaluated as described by Isiogugu and colleagues (Isiogugu *et al*., 2020).

Water immersion restraint stress-induced ulcer (WIRSIU) model

This was carried out as described by Isiogugu and colleagues (Isiogugu *et al*., 2020).

Experimental design

Each model used five (5) groups of animals (n = 5) designated as EIU +, EIU -, EIU 1000, EIU 2000, EIU 5000, WIRSIU +, WIRSIU -, WIRSIU 1000, WIRSIU 2000 and WIRSIU 5000. EIU + and EIU – received the standard/positive (omeprazole 20 mg/kg) and negative/placebo (distilled water 5 ml/kg) treatments, respectively. This also applies to WIRSIU + and WIRSIU – while EIU and WIRSIU 1000-5000 received 1000 mg/kg-5000 mg/kg treatments, respectively.

Preparation of tissue homogenate

Following slaughter of the rat, the stomach tissue was immediately excised, weighed and completely homogenized in phosphate buffer (10 mM KH_2PO_4-K_2HPO_4 buffer, pH 7.4; 0.1 mM EDTA). Homogenates were centrifuged at 5000 rpm for 20 min. The resulting supernatant was used to assay for oxidative stress indicators. Protein content of the supernatant was determined following the method of Lowry *et al*. (1951) using bovine serum albumin (BSA) as a standard.

Tissue malondialdehyde (MDA)

Malondialdehyde level, an end product of lipid peroxidation, was measured using a spectrophotometric method. The modified method of Jesús and Chad (2020) was adopted for the investigation. Thiobarbituric acid reacts with MDA to produce a stable chromogen that is quantified by spectrophotometry. The colour intensity of the chromogen is measured at 532 nm, which is directly proportional to MDA content. Lipid peroxidation in tissue was quantified by measuring the formation of thiobarbituric acid reactive substances (TBARS) based on the method of Stocks and Dormandy (1971). Equal volume of tissue homogenate was mixed with 20% trichloroacetic acid (1:1) and incubated at room temperature. Samples were centrifuged at 2500 x g for 10 min. Then 1.0 ml of 1% Thiobarbituric acid was added to the supernatant and samples were placed in boiling water bath (100 °C) for 15 min. The contents were cooled on ice and centrifuged for 15 min at 2500 x g. The absorbance (A) of the supernatant was read at 532 nm against a reagent blank using a spectrophotometer (Jenway 6305; Jenway, Essex, UK). A standard graph was prepared using different concentrations (0-20 nMoles) of MDA (Sigma, St. Louis, MO, USA). Lipid peroxidation (TBARS) level was expressed in nMol/mg protein.

Tissue superoxide dismutase (SOD)

Superoxide dismutase (SOD) activity in the tissue was determined according to the method developed by Misra and Fridovich (1972) and modified by Volkov and colleagues (Volkov *et al*., 2023). The test is based on the ability of SOD to inhibit the auto-oxidation of epinephrine to adrenochrome at pH 10.2. A volume of 0.5 ml of homogenate was diluted with equal volume (0.5 ml) of distilled water, followed by the addition of 0.25 ml of ice-cold ethanol and 0.15 ml of ice-cold chloroform. This was thoroughly mixed using a cyclo-mixer and then centrifuged at 2500 rpm for 10 min. The supernatant was mixed with 1.5 ml of carbonate buffer (0.05M, pH 10.2) and 0.5 ml of 0.5mM EDTA solution. The reaction was initiated by the addition of 0.4 ml of

3mM epinephrine (Sigma, St. Louis, MO, USA) and the change in absorbance per minute was measured at 480 nm against a reagent blank. The enzyme unit was defined as the change in absorbance per min at 50% inhibition of epinephrine to adrenochrome by superoxide dismutase. An enzyme calibration curve was prepared using 0-95 units of SOD (Sigma, St. Louis, MO, USA). SOD activity was expressed in U/mg protein.

Histopathological examination

Sections of the stomach were collected for histopathological examination. The samples were fixed in 10% phosphate buffered formalin for a minimum of 48 hours. The tissues were subsequently trimmed, dehydrated in 4 grades of alcohol (70%, 80%, 90% and absolute alcohol), cleared in 3 grades of xylene and embedded in molten wax. On solidifying, the blocks were sectioned, 5µm thick with a rotary microtome, floated in water bathe and incubated at 60˚C for 30 min. The 5µm thick sectioned tissues were subsequently cleared in 3 grades of xylene and rehydrated in 3 grades of alcohol (90%, 80% and 70%). The sections were then stained with Hematoxylin for 15 min. Blueing was done with ammonium chloride. Differentiation was done with 1% acid alcohol before counterstaining with Eosin. Permanent mounts were made on degreased glass slides.

Slide examination

The prepared slides were examined with a Motic™ compound light microscope using x4, x10 and x40 objective lenses. The photomicrographs were taken using a Motic™ 5.0 megapixels' microscope camera at x160 magnification.

Statistical analysis

Results obtained were analyzed using one-way ANOVA in SPSS version 23.0 and the data were expressed as Mean ± Standard Error of Mean (S.E.M). Differences between treated and control groups were evaluated further using LSD Post hoc test and considered significant at $p < 0.05$ and $p < 0.01$.

RESULTS

The effect of Zea *mays* starch slurry (ZM) on SOD and MDA in EIU model

In EIU model, ZM increased the gastric SOD levels compared to the negative control group. The increase in SOD levels was significant ($p < 0.001$) and dose-dependent with the 5000 mg/kg eliciting the best response. When compared to the standard treatment, the 5000 mg/kg elicited a better response. On the other hand, ZM produced decreased levels of MAD in EIU model in a dose-dependent manner (see table 1).

Effect of Zea *mays* starch slurry (ZM) on SOD and MDA in WIRSIU model

In WIRSIU model, ZM also increased the SOD levels compared to the negative control group. The increase in SOD levels was significant ($p < 0.05$) and dose-dependent with the 5000 mg/kg eliciting the best response. When compared to the standard treatment, the 5000 mg/kg elicited a somewhat similar response. Also, ZM produced decreased levels of MAD in WIRSIU which was also dose-dependent (see table 2).

Table 1: Effects of *Zea mays* starch slurry on SOD and MDA in EIU model

Treatment	Dose (mg/kg)	MDA	SOD
Omeprazole	20	0.60 ± 0.07	2.40 ± 0.24*
Distilled water		0.97 ± 0.06	0.71 ± 0.01
ZM	1000	0.78 ± 0.16	3.00 ± 0.91*
	2000	0.70 ± 0.03	3.40 ± 1.30*
	5000	0.66 ± 0.17	8.20 ± 0.25**

Values are expressed as mean ± SEM; n = 5; * and ** = $p < 0.05$ and $p < 0.01$, respectively; ZM = *Zea mays* starch slurry

Table 2: Effect of Zea mays starch slurry on SOD and MDA in WIRSIU model

Treatment	Dose (mg/kg)	MDA	SOD
Omeprazole	20	0.84 ± 0.07	2.72 ± 0.14*
Distilled water	20	2.14 ± 0.70	0.97 ± 0.02
ZM	1000	1.85 ± 0.59	1.54 ± 0.26
	2000	1.52 ± 0.20	1.61 ± 1.06
	5000	1.20 ± 0.06	3.13 ± 0.28*

Values are expressed as mean ± SEM; n = 5; * = $p < 0.05$; ZM = Zea mays starch slurry

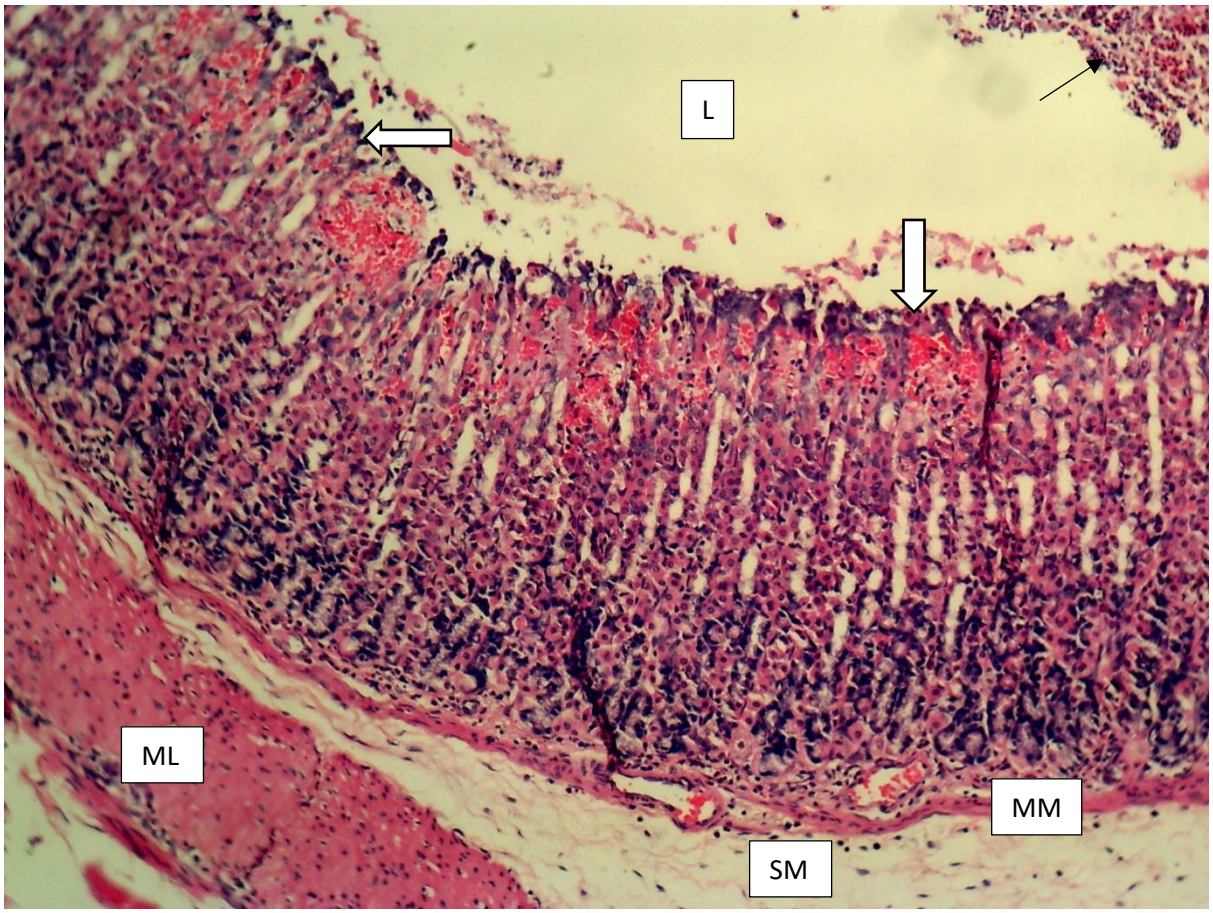

Figure 1: Histopathological view of EIU in rats that received omeprazole

The sections of the stomach presented in this group showed a minimal necrosis of the mucosal structures (black arrow) with mild hemorrhage and congestion of the blood vessels in the lamina propria. Lumen (L); Necrotic debris (black arrow); Muscularis mucosa (MM); Lamina propria (LP); Muscularis layer (ML). H&E x160.

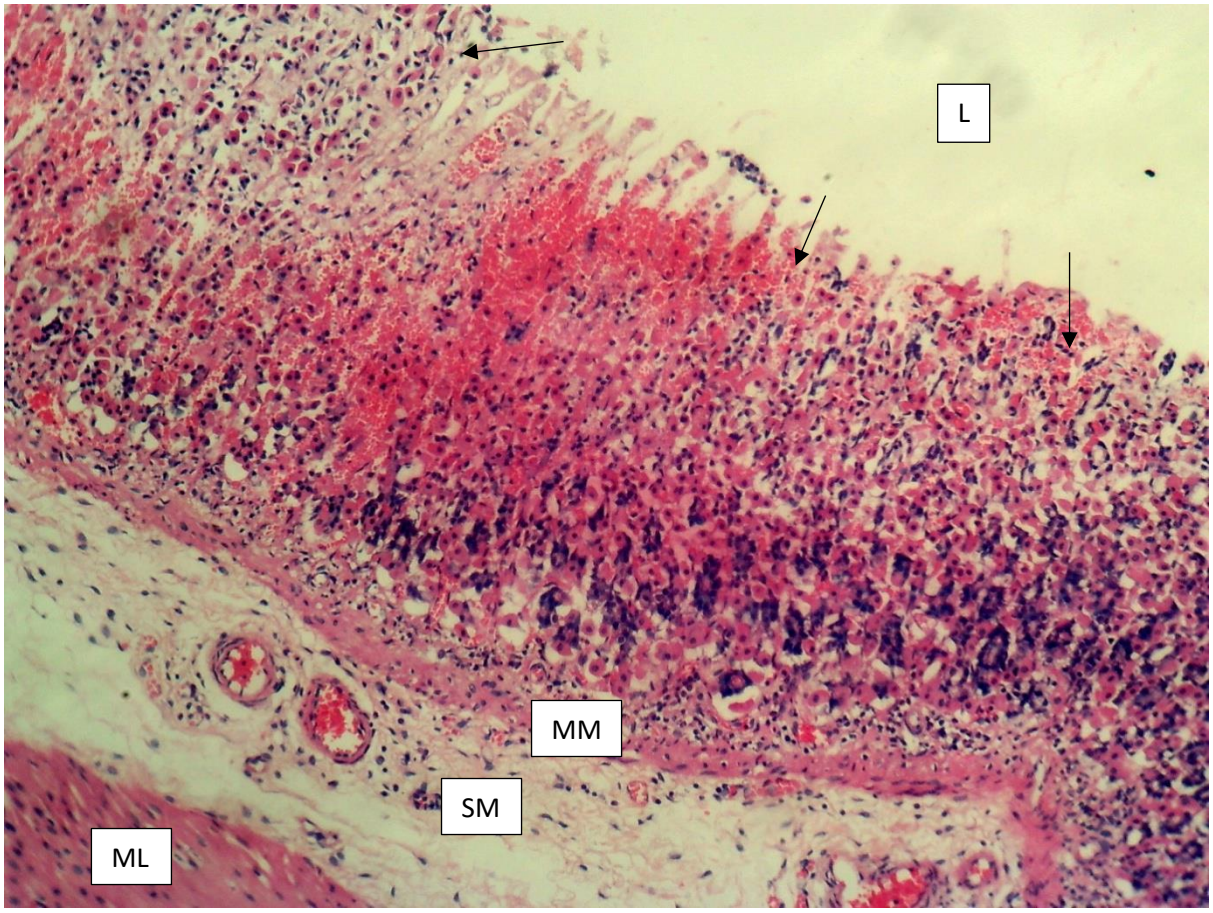

Figure 2: Histopathological view of EIU in rats that received distilled water
The sections of the stomach presented in this group showed a severe, widespread necrosis of the mucosa (black arrow) with severe hemorrhage and congestion of the blood vessels in the lamina propria. Lumen (L); Muscularis mucosa (MM); Lamina propria (LP); Muscularis layer (ML). H&E x160.

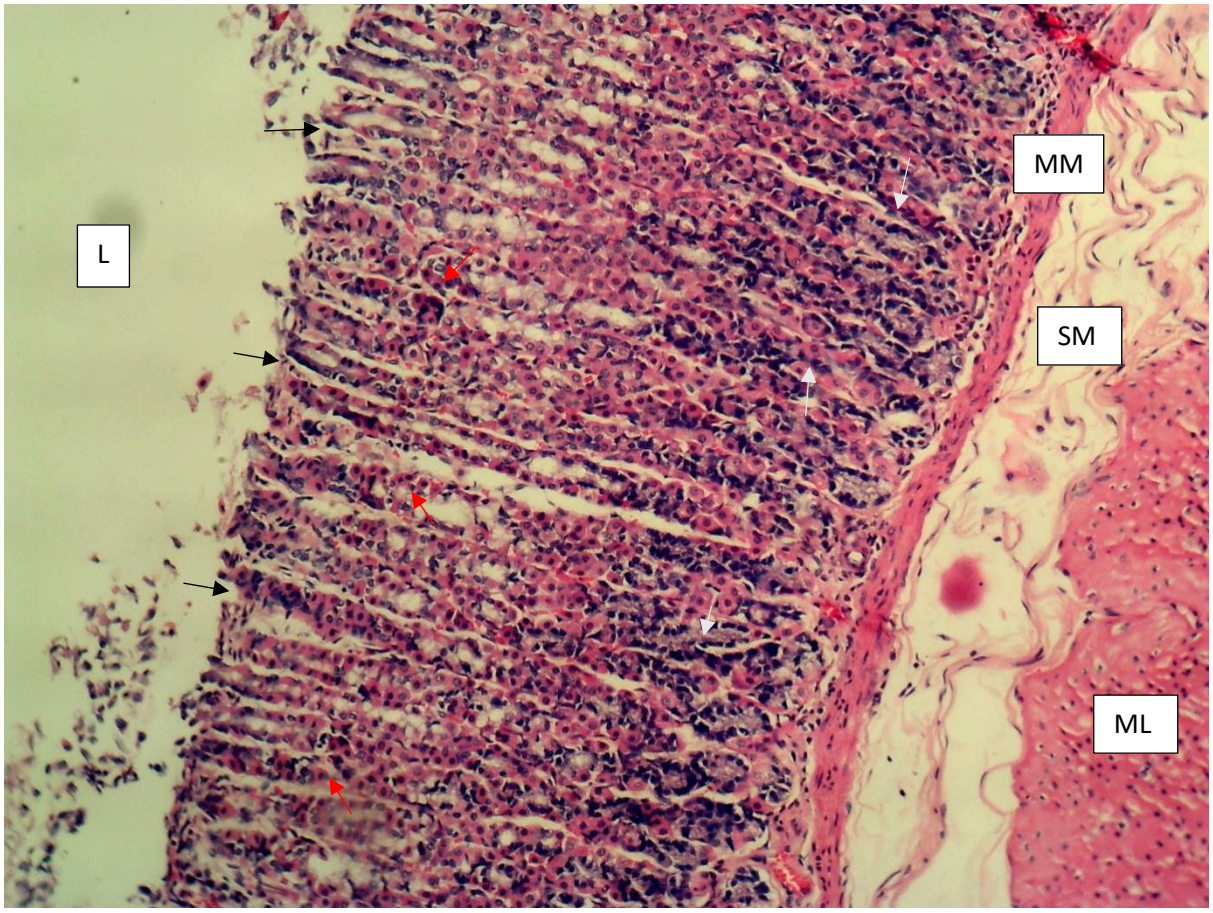

Figure 3: Histopathological view of EIU in rats that received 5000 mg/kg of ZM
Sections of the stomach presented in this group showed mild degeneration and necrosis of the mucosal cells in the upper layers of the mucosa though the histo-architecture was retained. The parietal cells were mostly affected (red arrow). Gastric pits (black arrow); Chief cells (white arrow); Lumen (L); Submucosa (SM); Muscularis mucosa (MM); Muscular layer (ML). H&E x160.

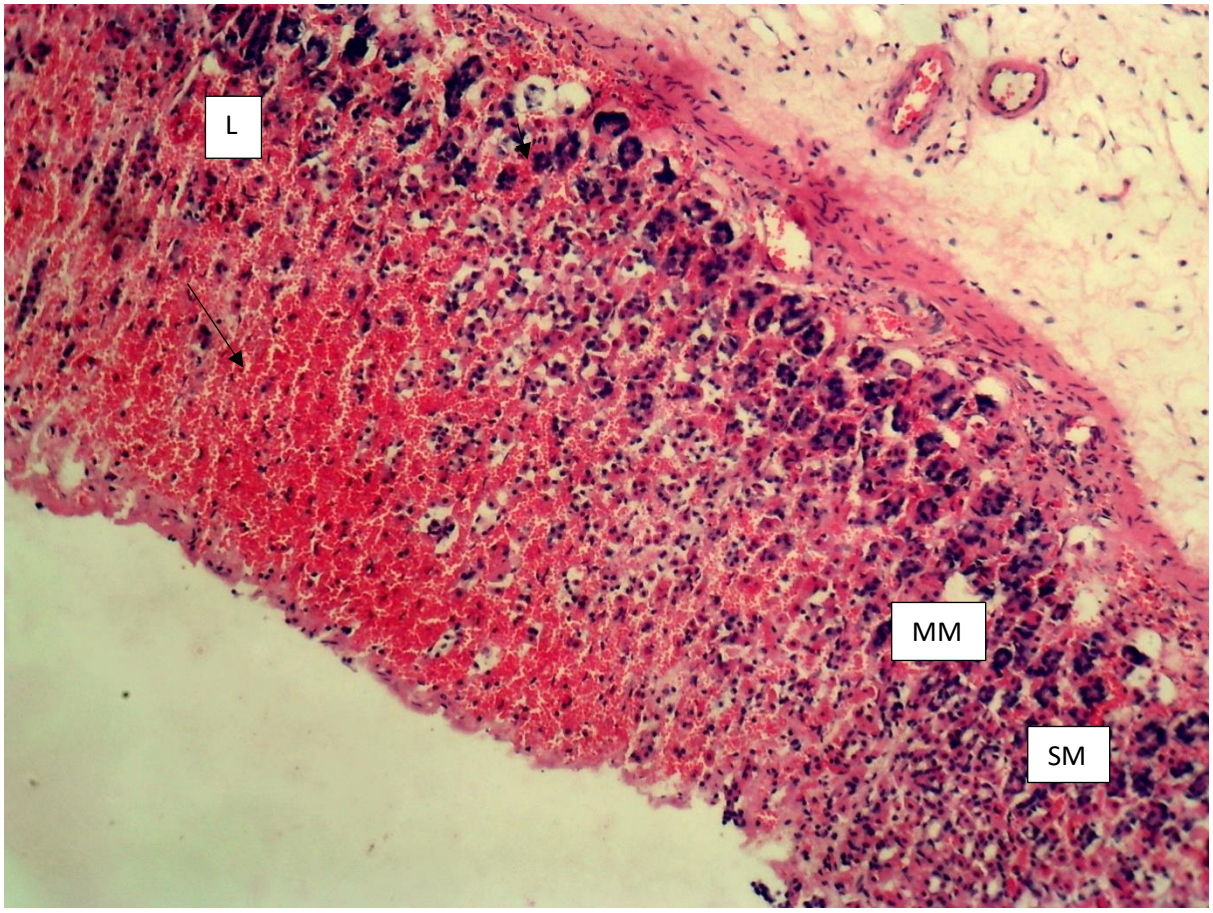

Figure 4: Histopathological view of EIU in rats that received 2000 mg/kg of ZM
The sections of the stomach presented in this group showed a moderate multifocally-widespread necrosis of the mucosal structures (black arrow) with hemorrhage. Lumen (L); Muscularis mucosa (MM); Sub mucosa (SM). H&E x160.

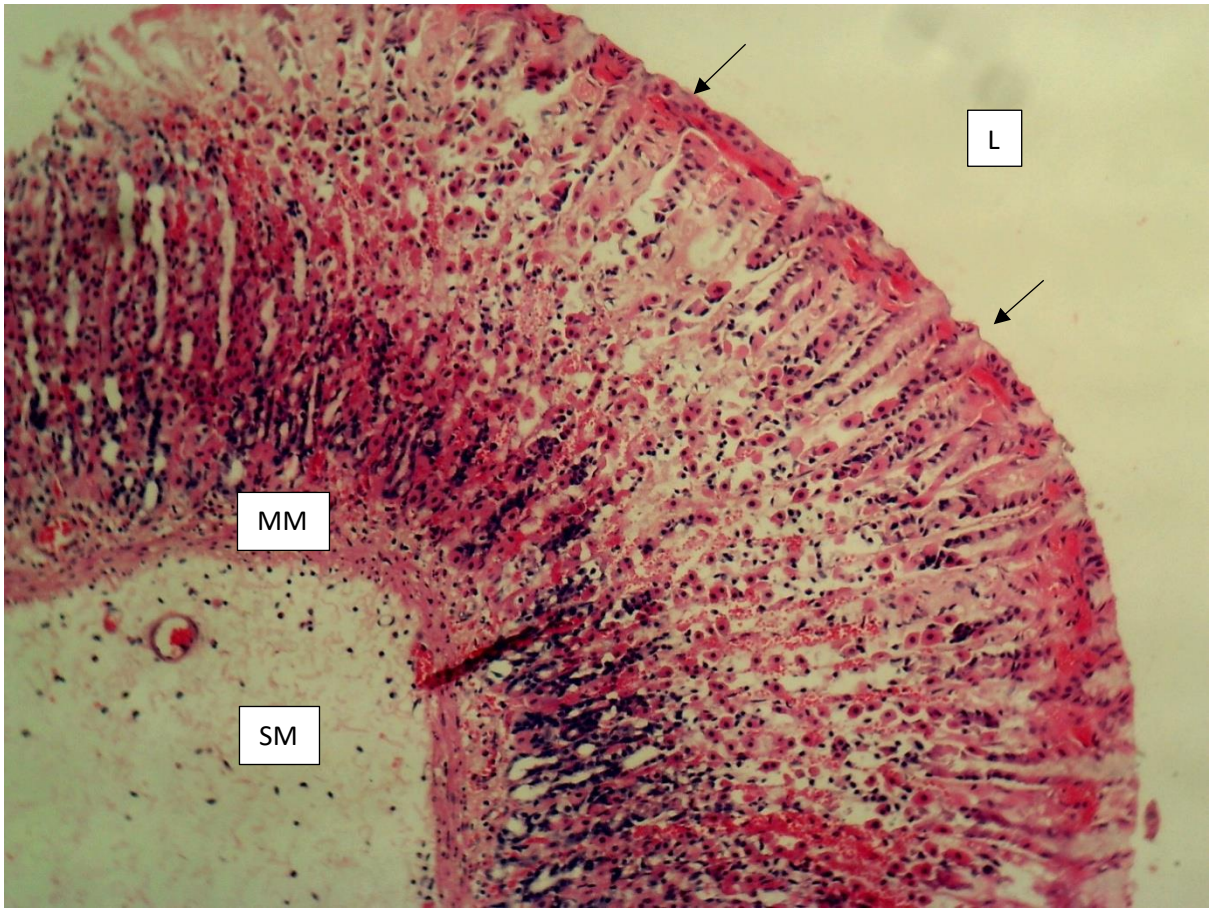

Figure 5: Histopathological view of EIU in rats that received 1000 mg/kg of ZM
The sections of the stomach presented in this group showed a multifocally-widespread necrosis of the mucosal structures (black arrow) with hemorrhage. Lumen (L); Muscularis mucosa (MM); Sub mucosa (SM). H&E x160.

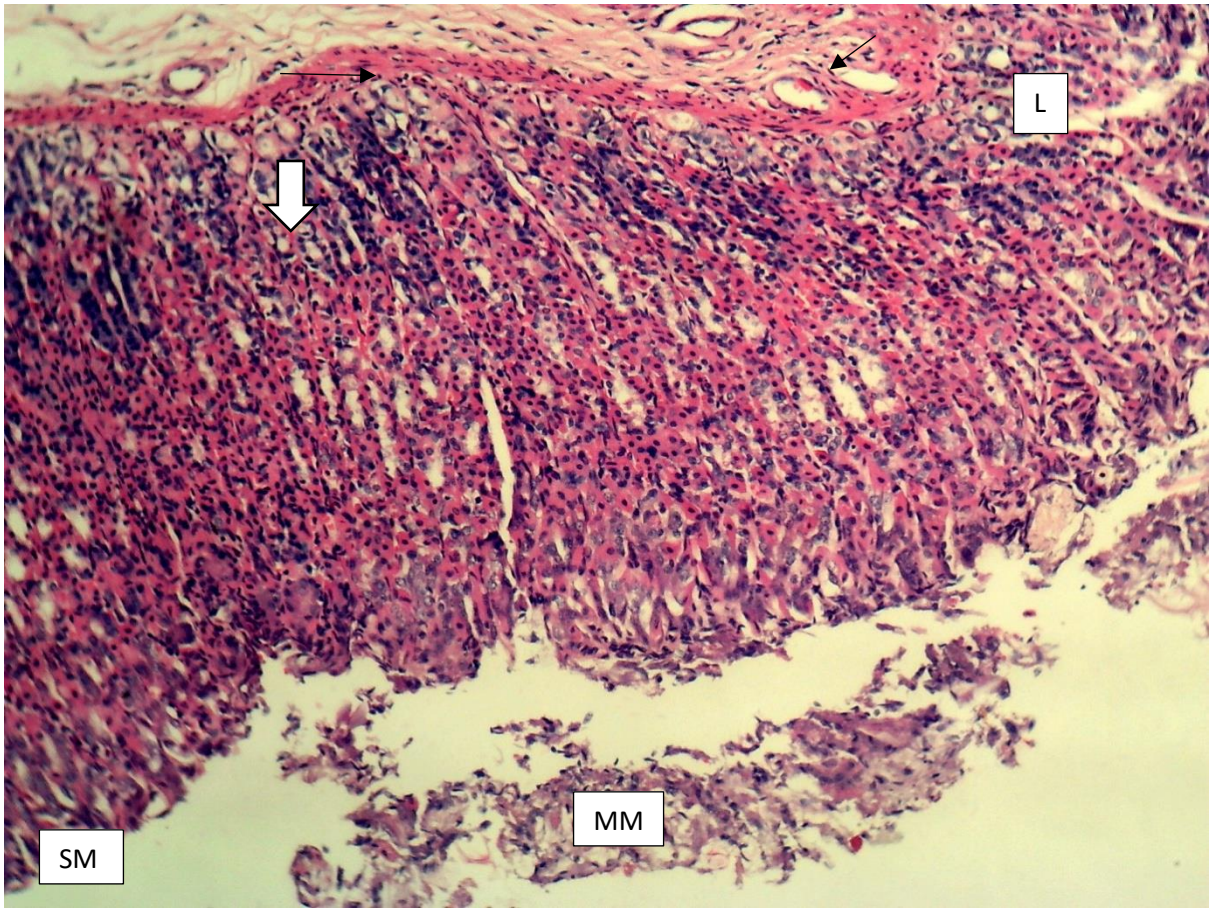

Figure 6: Histopathological view of WIRSIU in rats that received omeprazole
The sections of the stomach presented in this group showed a minimal area of mucosal necrosis mostly involving upper layers of the mucosa (white arrow). The affected areas showed influx of inflammatory cells and laying of collagen. Lumen (L); necrotic debris (black arrow); Muscularis mucosa (MM); Submucosa (SM). H&E x160.

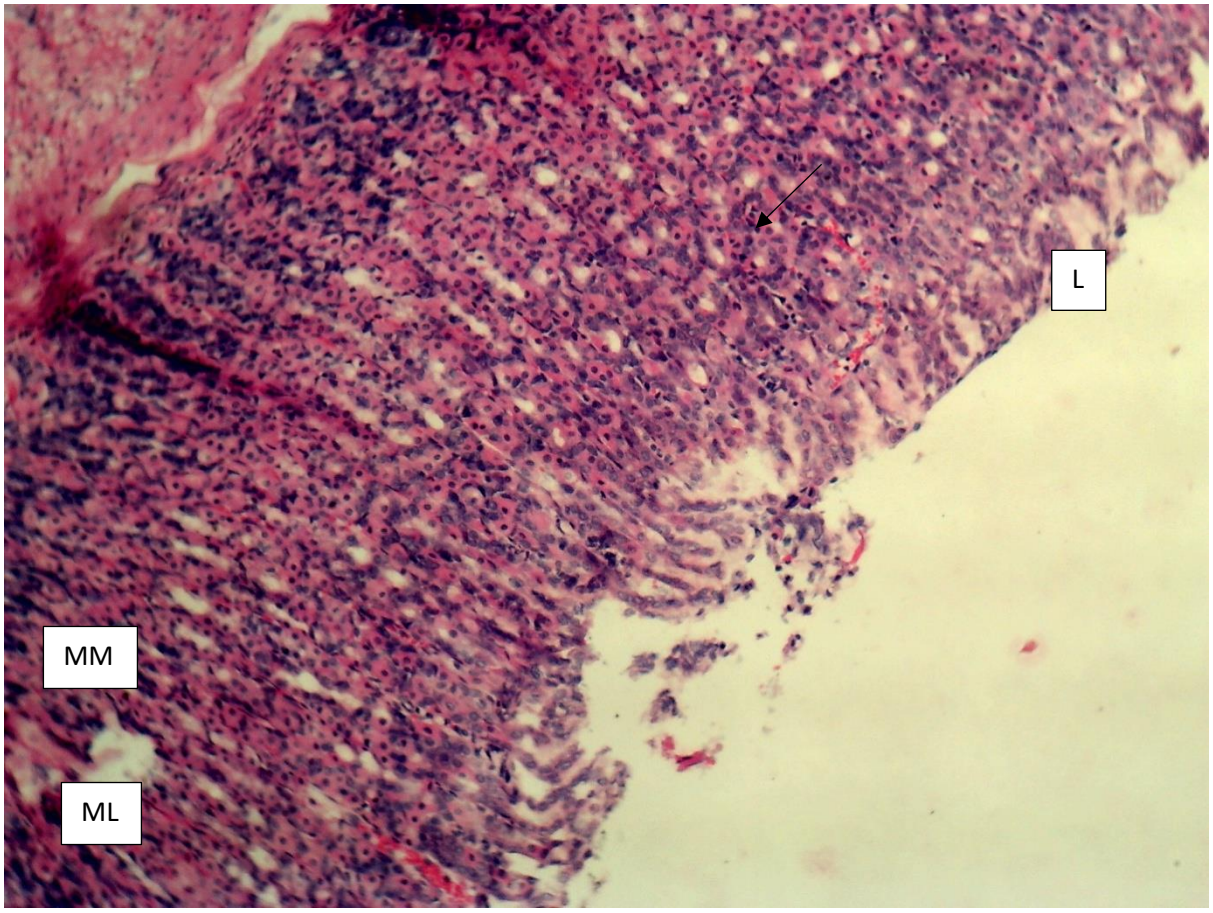

Figure 7: Histopathological view of WIRSIU in rats that received distilled water

The sections of the stomach presented in this group showed a severe multifocally-widespread necrosis of the mucosal structures (black arrow) involving mostly the upper layers of the mucosa. Lumen (L); Muscularis mucosa (MM); Submucosa (SM). H&E x160.

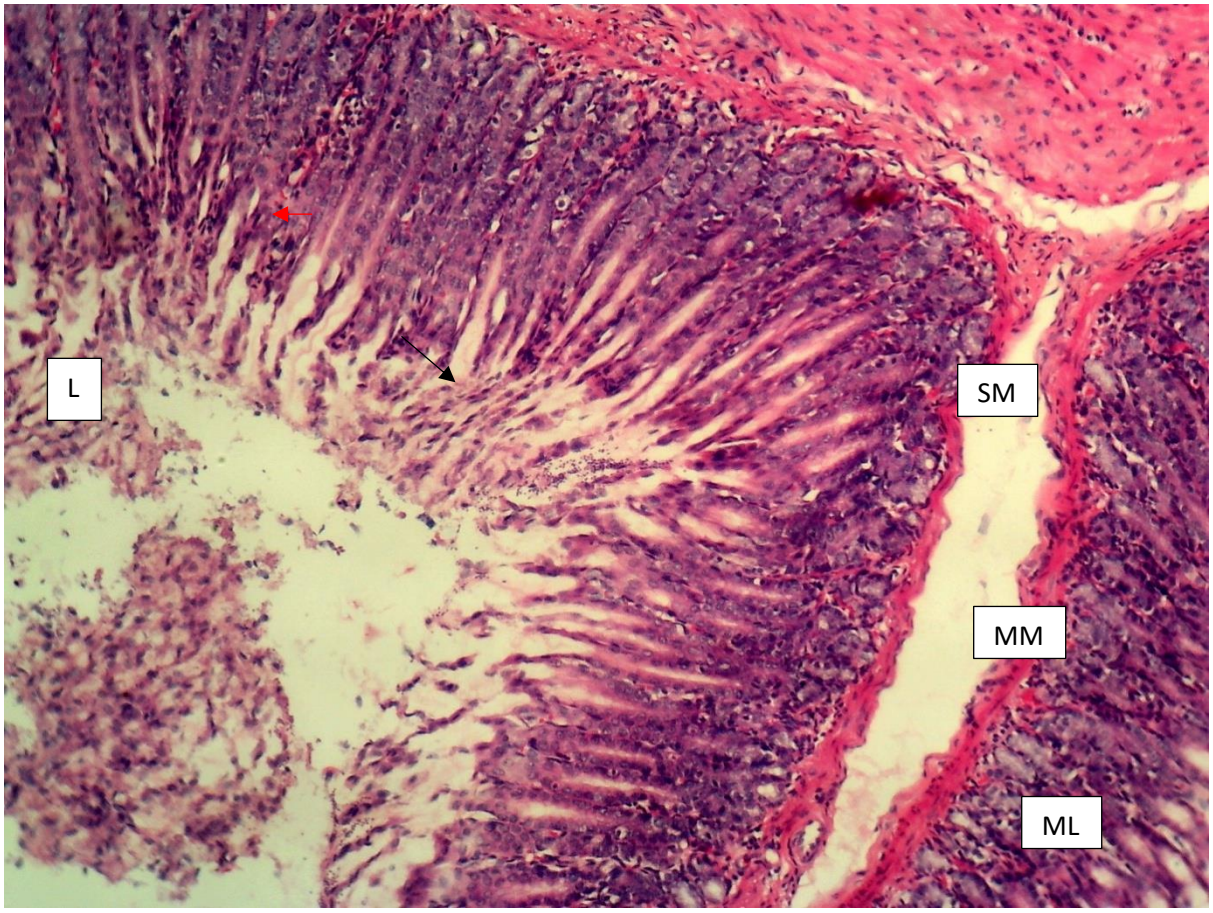

Figure 8: Histopathological view of WIRSIU in rats that received 5000 mg/kg of ZM
This group showed a mild multifocally-widespread necrosis of the mucosal structures (black arrow) involving mostly the upper layers of the mucosa. Lumen (L); Necrotic debris (red arrow); Muscularis mucosa (MM); Submucosa (SM). H&E x160.

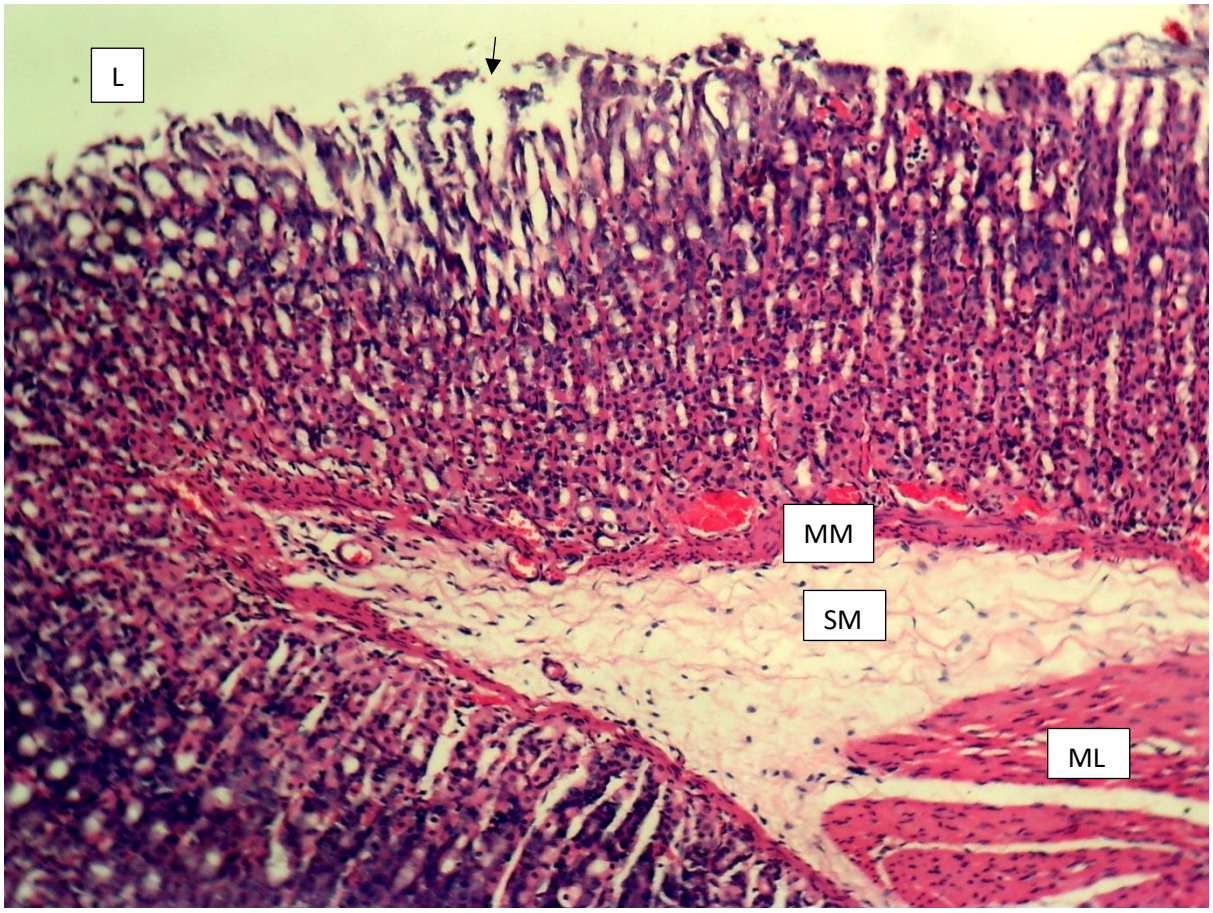

Figure 9: Histopathological view of WIRSIU in rats that received 2000 mg/kg of ZM
The sections of the stomach presented in this group showed a moderate multifocally-widespread necrosis of the mucosal structures (black arrow) involving mostly the upper layers of the mucosa. Lumen (L); Muscularis mucosa (MM); Submucosa (SM). H&E x160.

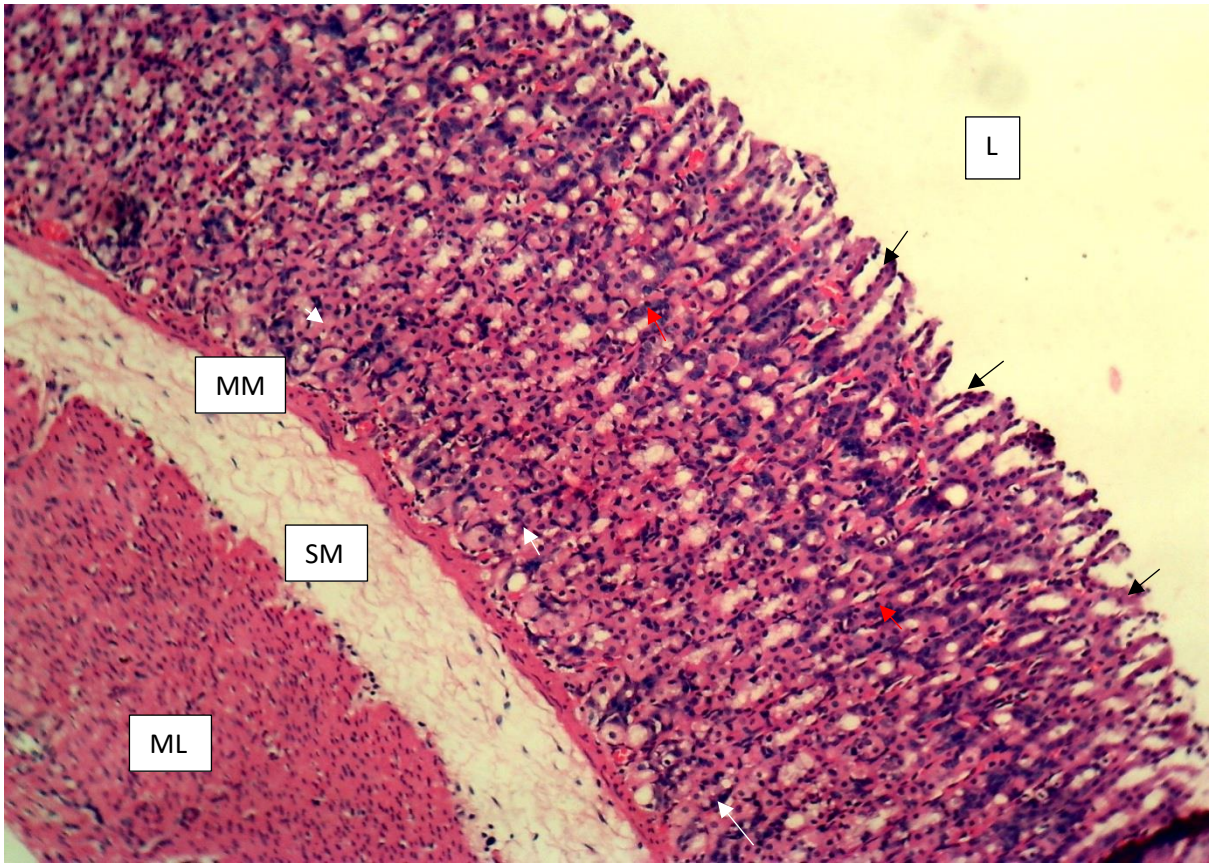

Figure 10: Histopathological view of WIRSIU in rats that received 1000 mg/kg of ZM
Sections of the stomach presented in this group showed a multifocally-widespread necrosis. The sections presented is that of the fundic mucosa of the of the glandular stomach. Gastric pits (black arrow) are lined by columnar epithelium, serving as the outlet for the fundic gland secretions. The gastric glands are lined by normal parietal cells (red arrow) and chief cells (white arrow). Lumen (L); Submucosa (SM); Muscularis mucosa (MM); Muscular layer (ML). H&E x160.

DISCUSSION

According to Aguwa (2004), peptic ulcer results by the imbalance between the aggressive factors (gastric acid, pepsin, bile salts, *H. pylori* and NSAIDs) and the mucosa defense mechanisms (mucosal blood flow, mucus, mucosal bicarbonate secretion, mucosal cell restitution and epithelial cell renewal). Gastric ulceration occurs when the mucosal defences fail with the aggressive factors prevailing (Aguwa *et a*l., 2012). Pepsin and acid are relatively less important causative agents, but defects in the defensive mechanism of gastric mucosa are the first step towards ulcer formation (Anand, 2019). Generally, various non-specific methods are used to restore these imbalances including regular food intake, adequate rest and avoidance of ulcerogenic agents (e.g., tobacco, alcohol and coffee). Their aims are to satisfy and possibly block the gastric acid secretion or to enhance the mucosal defense mechanisms. Increase of mucus secretions produced by the gastric mucosal cells can prevent gastric ulceration that is closely linked to the pathogenesis and healing of gastrointestinal lesions (Chanda *et al*., 2011, Palle *et al*., 2018). It can decrease stomach-wall friction during peristalsis and provide an effective barrier to back diffusion of hydrogen ions (Anand, 2019). On the other hand, enhancement of the mucosal defense mechanisms can be achieved through escalating mucus production, stabilizing the surface epithelial cells or interfering with the prostaglandin synthesis (Khushstar *et al*., 2009). In addition, there are also drugs, such as proton pump inhibitors (PPI), histamine-2 (H2) antagonists, anticholinergics and antacids, used in the treatment of ulcer (Khushstar *et al*., 2009).

In this present study, histopathological and biochemical parameters such as SOD and MDA were analyzed in rats. The microscopically view showed areas of the stomach with haemorrhagic injuries, wide submucosal edema, mucosal frangibility, and damage to the epithelial cell of gastric tissue. Oxidative stress has been linked to many pathological processes and ROS is the by-product of aerobic metabolism which consists of superoxide anion, hydrogen peroxide, and hydroxyl radicals. MDA is the final product of lipid peroxidation and it is used to determine the levels of lipid peroxidation (Cordiano *et al*., 2023). An

increase in MDA content correlates to an increase in tissue damage. Decrease in the activity of SOD might lead to some harmful effects. Superoxide and hydroxyl radicals are main intermediaries of oxidative stress that has important role in most of medical conditions. Thus, removing superoxide and hydroxyl radical has efficient effect to protect against disease (Zheng *et al*., 2023; Cordiano *et al*., 2023).

Our findings show that ethanol and stress altered the biochemical parameters and integrity of the gastric mucosa to a considerable extent. But upon the administration of ZM, it offered protection to the integrity of the gastric mucosa while enhancing the activity of the anti-oxidant system.

Ethanol is one of the common causes of gastric ulcer in human. Ethanol-induced gastric injury is associated with significant production of oxygen free radicals leading to increased lipid peroxidation, which causes damage to cell and cell membrane (Neda *et al*., 2019). Also, ethanol produces necrotic lesions by direct necrotizing action which in turn decreases defensive factors (the production of mucus and secretion of bicarbonate), increases lipid peroxidation, and decreases superoxide dismutase, GSH levels, and catalase (Neda *et al*., 2019). From the result of the ethanol-induced ulcer model, it showed that oral consumption of ethanol is harmful to the gastric mucosa which caused damage of gastric mucosa wall. The result of the histopathological assessment of the stomach of the EIU showed severe widespread necrosis of the mucosa with haemorrhage and congestion of the blood vessels in the lamina propria. The EIU 1000 showed multifocally-widespread necrosis of the mucosal structures with hemorrhage while EIU 5000 showed mild degeneration and necrosis of the mucosal cells in the upper layer of the mucosal through the histo-architecture was retained. The parietal cells were mostly affected. Ethanol damages the mucosal layer as the important protecting layer of the gastrointestinal luminal cavity which banned straight interaction with the digestive enzymes (Hajirezaie *et al*., 2015). The study on the gastroprotective effect of *Zea mays* starch slurry against ethanol-induced ulcer in comparison to omeprazole (widely used drug approved for gastric ulcer treatment) on the biochemical parameters showed a significant increase in the level of the antioxidants, SOD. Administration of *Zea mays* starch slurry (1000, 2000, and 5000 mg/kg) caused significant increase of SOD level in the stomach tissue with a corresponding reduction of MDA level in the stomach. The increase in the level of SOD and decrease in MDA may be attributed to the presence of flavonoid, tannins and terpenoids in maize which possess strong antioxidant free radical scavenging activity (Isiogugu *et al*., 2020). This corroborates the fact that high level of antioxidants (SOD) and low level of oxidative stress marker (MDA) is required for balance of metabolic process (Zheng *et al*., 2023; Cordiano *et al*., 2023).

Water immersion restrain stress-induced ulcer cause ulcer by stimulation of gastric acid secretion and a reduction in mucosal microcirculation and mucus content (Soni *et al*., 2014; Rujjanawate *et al*., 2005). Histopathological view of the stomach of stress induced rats showed areas of multifocal necrosis involving the upper layers of the mucosa. The WIRSIU+ gave a near normal histomorphology of the mucosa. Omeprazole performed its function as a proton pump inhibitor and acid inhibitor agent which protected gastric mucosa (Khushstar *et al*., 2009). The result on the gastroprotective effect shows that *Zea mays* starch slurry decreased MDA but increased SOD. This shows that high level of antioxidants (SOD) and low level of oxidative stress marker (MDA) is required for balance of metabolic process (Zheng *et al*., 2023; Cordiano *et al*., 2023).

In this study, ZM was found to inhibit the depletion of the stomach-wall mucus caused by the ethanol administration. This antiulcer activity could be attributed to *Zea mays* phytochemical constituents which are flavonoids, tannins, resins, saponins, terpenoids, proteins, reducing sugars and carbohydrates (Isiogugu *et al*., 2020). In summary, biochemical estimations showed a significant anti-oxidant effect of ZM slurry in both EIU and WIRSIU models.

CONCLUSION

From the study, it can be concluded that *Zea mays* afforded significant antiulcer activity by enhancing antioxidant potential of the gastric mucosa, thereby reducing mucosal damage.

Conflict of Interest

The authors have declared no conflict of interest associated with this work.

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