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# CURATIVE EFFECTS OF GUM ARABIC AND *BOSWELLIA* SPECIES ON ACUTE RENAL FAILURE IN EXPERIMENTAL RATS

**[18]**

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## ABSTRACT

Acute renal failure (ARF) was induced by glycerol or paracetamol in experimental rats to evaluate the curative effects of gum Arabic and *Boswellia* sp. through different blood biochemical assays and hematological analyses. Results revealed presence of significant ($P<0.05$) increases in the levels of urea, creatinine, potassium ($K^+$), sodium ($Na^+$), chloride ($Cl^-$) and blood acidity ($H^+$), and significant ($P<0.05$) decreases in the levels of calcium ($Ca^{+2}$) and bicarbonate ($HCO_3^-$) in the rats treated only with glycerol or paracetamol in the positive control groups compared to the negative control group. These results indicated that glycerol or paracetamol caused ARF in these groups of rats whereas the blood analyses illustrated ARF symptoms such as increasing of urea and creatinine, hyperkalemia, hypocalcemia, hypoglycemia, blood acidosis and anemia occurring in the positive control groups. The blood analyses also illustrated recovery of these symptoms in the treated rats with gum Arabic and *Boswellia* sp. in drinking water (10% w/v) for 30 days. This indicated the curative effects of gum Arabic and *Boswellia* sp. against ARF induced by glycerol or paracetamol as evidenced by restoring the kidney function tests such as urea, creatinine, blood electrolytes and other parameters like serum glucose, proteins and hematological indices to their normal values during the experiment period. The therapeutic effects of both plants against ARF may be due to their antioxidant and/or anti-inflammatory activity.

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## INTRODUCTION

Acute renal failure (ARF) is characterized by a rapid, potentially reversible, decline in renal function including rapid fall in glomerular filtration rate (GFR) and retention of nitrogenous waste products over a period of hours or days. The mortality rate of patients with ARF has remained 25–70% despite the use of various pharmacologic agents. Therefore, it continues to be a frequent threatening complication following trauma, complex surgical procedures, and in patients hospitalized in intensive care units **(Lameire et al 2006)**. ARF increases the risk of death in patients after thoracoabdominal aortic surgery, bone marrow transplantation, amphotericin B therapy, in patients with liver cirrhosis and in cardiac surgery **(Chertow et al 1998)**.

Glycerol-induced ARF is characterized by myoglobinuria, tubular necrosis and enhanced renal vasoconstriction **(Karam et al 1995)**. The pathogenic mechanisms involved in glycerol-induced renal failure include ischemic injury, tubular nephrotoxicity caused by myoglobin, and the renal actions of cytokines released after rhabdomyolysis **(Curry et al 1989)**. Rhabdomyolysis is the syndrome characterized by breakdown of striated muscle with massive release of myoglobin into the extracellular fluid and blood circulation leading to filtration of myoglobin to renal tubules. Rhabdomyolysis provokes acute tubular necrosis because myoglobin forms obstructing tubular casts and myoglobin also leads to intra-renal vasoconstriction. The large numbers of disorders known to cause rhabdomyolysis include intrinsic muscle dysfunction (including trauma, burns, intrinsic muscle disease, and excessive physical exertion), metabolic disorders, hypoxia, drugs, toxins, infections, temperature extremes and idiopathic disorders **(Vanholder et al 2000)**. In general, about 10–40% of cases with rhabdomyolysis develop ARF and it accounts for 2–15% of all cases of ARF. The model for studying this form of ARF is obtained in the rats by intramuscular injection of glycerol **(Singh et al 2012)**. There is enhanced generation of hydrogen peroxide in renal cortex in rats with glycerol-induced ARF.

Acetaminophen (paracetamol) is most widely used in the world as an analgesic and antipyretic drug that is safe at therapeutic dosages. However, it is also known to cause hepatic necrosis and renal failure in humans **(Hengy et al 2009)** and animals **(Ghosh et al 2010)** in overdoses. In human, acetaminophen represents a growing cause of renal failure in current medical practice. Acetaminophen-induced renal insufficiency is consistent with acute tubular necrosis, an increase in the plasma creatinine level and a decrease in the GFR. Oxidative stress is reported to play a role in the pathogenesis of acetaminophen-induced renal damage whose metabolism occurs *via* cytochrome P450 (CYP) enzymes in both the liver and the kidney. In renal tissues, prostaglandin synthetase and N-deacetylase enzymes play a key role in the formation of free radicals and their metabolites. At higher doses, acetaminophen is shunted through these pathways leading to the increased production of reactive oxygen/nitrogen metabolites, gradual GSH depletion, formation of lipid peroxidative products leading to cell death and renal failure **(Abdel-Zaher et al 2008, Bessems & Vermeulen, 2001, Gamal El-Din et al 2003 and Ghosh et al 2010)**.

In recent years, great efforts have been focused on natural compounds and herbal constituents without toxic effects to provide novel therapeutic agents for ARF. Several authors proved the protective effects of some natural compounds and herbal constituents against glycerol-induced ARF in rats such as γ-aminobutyric acid (GABA) **(Kim et al 2004)**, flavonoid naringin **(Singh et al 2004)**, Oyster Mushroom (*Pleurotus ostreatus*) **(Sirag, 2009)**, ginsenosides (extracted from ginseng) **(Zhang et al 2010)** and L-citrulline **(Liu et al 2013)**. While other authors proved the protective effects of some natural compounds and herbal constituents against acetaminophen-induced ARF in rats such as curcumin **(Cekmen et al 2009)**, garlic oil **(Gulnaz et al 2010)**, clover flowers honey **(Ramadan and Schaalan, 2011)**, thyme (*thymus vulgaris*) extract **(Abd El-Kader and Mohamed, 2012)**, L-carnitine **(Gebaly et al 2012)**, ethanolic extract of stem bark of butterfly tree (*Bauhinia purpurea*) **(Reddy et al 2012)** and mulberry (*Morus sp.*) tea **(Salih et al 2015)**.

Gum Arabic (GA) is a water-soluble polysaccharide, obtained from stems of *Acacia senegal* trees as gummy exudates and it is metabolized in colon by normal flora into organic acids and volatile fatty acids. GA is widely used in the pharmaceutical industries as an emulsifier and suspending agent for insoluble drugs as well as in food industries **(Ali et al 2009)**. Administration of GA to rats post-irradiation by gamma rays had significantly ameliorated radiation-induced changes **(Hussein, 2008)**. GA possessed a potent superoxide scavenging activity so it gave a protective effect against acetaminophen-induced hepatotoxicity in mice **(Gamal El-Din et al 2003)**. Administration of gum Arabic in combination with aspirin in rats exhibited a protective effect against intestinal mucosal toxicity compared with the control **(Nasif et al 2011)**. GA treatment decreased blood pressure and proteinuria in diabetic mice, and consequently possessed a beneficial role in diabetic nephropathy **(Nasir et al 2012)**. GA exhibited a potential protective effect against doxorubicin-induced cardiotoxicity in rats **(Elderbi et al 2014)**. GA possessed a protective effect against chronic kidney disease induced by adenine **(Ali et al 2013 and Al-Suleimani et al 2015)**. GA exhibited a protective effect against hepatic oxidative stress in alloxan-induced diabetes in rats **(Ahmed et al 2015)**. Pretreatment with GA exhibited protection against cisplatin and gamma radiation-induced renal cellular damage in rats **(Mohamed et al 2015)**.

Frankincense (*Boswellia sp.*) that is resinous exudates from trees of genus *Boswellia*, has been used for centuries in ceremonial, cosmetic, cultural and as a traditional medicine to treat a variety of ailments especially inflammatory diseases such as asthma, arthritis and chronic bowel diseases. Boswellic acids are the active compounds of frankincense and AKBA (3-O-acetyl-11- keto-β-boswellic acid) is the most important and effective acid among them **(Hamidpour et al 2013)**. Methanol soluble fraction of *Boswellia serrata* exhibited a protective action against gentamicin-induced nephrotoxicity in rats **(Alam et al 2011)**. *Boswellia serrata* extract exhibited anti-inflammatory and antioxidant properties against ulcerative colitis induced by acetic acid in rats **(Hartmann et al 2014)**. Aqueous extract of *Boswellia papyrifera* stem bark possessed a curative effect against acetaminophen-induced kidney damage in rats **(Abdulmumin et al 2014)**.

The present study was aimed to evaluate (i) the adverse effects induced by intramuscular injection of glycerol or oral administration of acetaminophen in an overdose for experimental rats (ii) the curative effects of gum Arabic and *Boswellia* administered as suspension solutions in drinking water (10% w/v) for the rats to cure these adverse effects.

## MATERIALS AND METHODS

### Materials

Frankincense (*Boswellia sp.*) and gum Arabic were purchased from Agricultural Seeds, Spices and Medicinal Plants Co., El-Azhar St., Cairo, Egypt. Acetaminophen (paracetamol) was obtained as a gift sample from El-Nile Pharmaceutical Co., Cairo, Egypt. Glycerol was purchased from El-Nasr Chemical Co., Cairo, Egypt. All other chemicals used in this work were of analytical grade.

### Reagent kits

Aspartate aminotransferase (AST), alanine aminotransferase (ALT), albumin, total protein, total bilirubin, urea, creatinine and glucose kits were obtained from Egyptian Company for Biotechnology, Obour city, Industrial area, block 19A, Cairo, Egypt.

### Methods:

### Experimental animals

Thirty five male Albino rats of Wistar strain weighing about 100g were obtained from the farm of experimental animals in Helwan, Cairo, Egypt. The rats were housed under normal laboratory conditions. The rats had free access food and water *ad libitum* during the experiment period.

### Experimental design

Rats were randomly divided into 7 groups (n = 5), and the first one served as a negative control. While groups (2, 3 & 4) were deprived of water for 16 h, and received a single dose of glycerol solution (50% v/v, 8 ml/kg) by an intramuscular injection in both hind limbs **(Kondaa et al 2015)**. Groups (5, 6 & 7) received orally a single dose of paracetamol as a suspension solution in water (750 mg/kg) by using a stomach tube **(Reddy et al 2012)**. After two days of administration, induction of ARF was tested in these groups by investigation of renal function tests (serum urea, creatinine and potassium) which increased extremely compared with those in the negative control. After ARF induction, groups (2 & 5) served as positive controls while groups (3 & 6) were given gum Arabic, and groups (4 & 7) were given *Boswellia* as suspension solutions in drinking water (10% w/v). The experiment was performed for 30 days.

### Blood sampling and biochemical assays

Blood samples were collected in clean centrifuge tubes from retro-orbital venous plexus of all animals by using capillary tubes. After that, serum was separated from the collected blood samples by centrifugation and kept in a refrigerator at 4$^{o}$C until analysis. Biochemical measurements of AST, ALT **(Young, 1990)**, Urea **(Tietz, 1990)**, Creatinine **(Bowers and Wong, 1980)**, Total protein **(Gornall et al 1949)**, Albumin **(Doumas et al 1971)**, Total bilirubin **(Malloy and Evelyn, 1937)** and Glucose **(Tietz, 1995)** were applied.

### Blood acidity and electrolytes analyses

Blood acidity (pH) and electrolytes such as sodium ($Na^{+}$), potassium ($K^{+}$), calcium ($Ca^{+2}$), chloride ($Cl^{-}$) and bicarbonate ($HCO_3^{-}$) were analyzed by using a blood gas analyzer (ABL800, Radiometer, Denmark).

### Hematological analyses

Complete blood count (CBC) analyses were performed in blood samples which were collected in tubes containing EDTA. Hematological parameters like hemoglobin (Hb), hematocrit (Hct) or packed cell volume (PCV), red blood cells (RBCs), white blood cells (WBCs) and platelets (PLTs) were analyzed by using a hematology analyzer (CD1800, Abbott, USA).

### Statistical analysis

Results are presented as means ± standard error of three replicates. The recorded data were treated statistically using the one way analysis of variance (ANOVA). The means were compared by Least Significant Difference test (LSD) at P<0.05. Statistical analyses were performed using SPSS statistical software (IBM SPSS Statistics, version 20) **(Snedecor and Cochran, 1980)**.

## RESULTS AND DISCUSSION

The adverse effects of both compounds (glycerol by intramuscular injection and paracetamol by oral administration) induced nephrotoxicity, and the remedial effects of both plants (gum Arabic and *Boswellia sp.*) were monitored through different blood biochemical assays and hematological analyses. The obtained data were classified into the following items:

### 1. Effect of gum Arabic and *Boswellia* sp. on the renal profile in the rats affected with ARF induced by glycerol or paracetamol.

**Table (1)** shows the effect of gum Arabic and *Boswellia sp*. on the renal profile (serum urea and creatinine) analyzed at the end of experiment period (30 days) in the rats affected with ARF induced by glycerol or paracetamol. The results showed significant ($P<0.05$) increases in the levels of serum urea in the rats treated only with glycerol or paracetamol and without any plants in the positive control groups (143 ± 3.6 & 130 ± 2.2 mg/dl, respectively) compared to the negative control group (36 ± 2.6 mg/dl). The results also showed significant ($P<0.05$) increases in the levels of serum creatinine in the rats treated with glycerol or paracetamol in the positive control groups (2.5 ± 0.4 & 1.8 ± 0.1 mg/dl, respectively) compared to the negative control group (0.7±0.1mg/dl). These results proved that both glycerol and paracetamol compounds caused ARF in these groups as indicated by these parameters. Evidently, glycerol as ARF inducer was more effective than paracetamol. The curative effects of both plants against ARF induced by both compounds were noticed as indicated by restoring the levels of these parameters to their normal values. No significant difference was found between the curative efficiency of gum Arabic and *Boswellia sp*. in the rats treated with glycerol and paracetamol. These results are in agreement with those obtained by **Rafiq et al (2012) and Abdulmumin et al. (2014)**.

### 2. Effect of gum Arabic and *Boswellia* sp. on the blood acidity in the rats affected with ARF induced by glycerol or paracetamol.

**Table (2)** reveals the effect of gum Arabic and *Boswellia sp*. on the blood acidity ($H^+$) in the rats affected with ARF induced by glycerol or paracetamol. The results revealed significant ($P<0.05$) increases in the blood acidity ($H^+$) as indicated by decreasing the levels of pH for the rats treated with glycerol or paracetamol in the positive control groups (7.20±0.42 & 7.21 ± 0.46, respectively) compared to the negative control group (7.39 ± 0.02). This symptom is called blood acidosis which may be due to the retention of hydrogen ions ($H^+$) in the blood owing to renal dysfunction. The remedial effects of both plants against ARF induced by both compounds were observed as indicated by restoring the levels of this parameter to its normal value.

**Table 1.** Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the renal profile (serum urea and creatinine) in the rats affected with ARF induced by glycerol or paracetamol.

| Treatments | Urea (mg/dl) | Creatinine (mg/dl) |
|---|---|---|
| Control | 36±2.6$^c$ | 0.7±0.1$^c$ |
| Glycerol | 143.3.6$^a$ | 2.5±0.4$^a$ |
| Glycerol+ G.A. | 52±1.1$^c$ | 1.3±0.3$^c$ |
| Glycerol + B.S | 38±1.9$^c$ | 1.0±0.2$^c$ |
| Paracetamol | 130±2.2$^b$ | 1.8±0.1$^b$ |
| Paracetamol + G.A | 42±1.9$^c$ | 0.8±0.1$^c$ |
| Paracetamol + B.S | 44±2.3$^c$ | 1.0±0.1$^c$ |

The data are presented as means ±SE calculated from three replicates.

Different letters refer to significant differences at ($P<0.05$).

**Table 2.** Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the blood acidity ($H^+$), potassium ($K^+$) and calcium ($Ca^{+2}$) in the rats affected with ARF induced by glycerol or paracetamol.

| Treatments | pH | Potassium (mmol/L) | Calcium (mmol/L) |
|---|---|---|---|
| Control | 7.39±0.02$^a$ | 3.7±0.1$^c$ | 1.1±0.02$^a$ |
| Glycerol | 7.20±0.42$^b$ | 5.2±0.2$^a$ | 0.5±0.04$^b$ |
| Glycerol+ G.A. | 7.34±0.14$^a$ | 4.0±0.2$^c$ | 1.0±0.04$^a$ |
| Glycerol + B.S | 7.36±0.29$^a$ | 3.7±0.2$^c$ | 0.9±0.03$^a$ |
| Paracetamol | 7.21±0.46$^b$ | 4.8±0.1$^b$ | 0.5±0.03$^b$ |
| Paracetamol + G.A | 7.35±0.01$^a$ | 3.8±0.2$^c$ | 0.9±0.02$^a$ |
| Paracetamol + B.S | 7.34±0.14$^a$ | 3.7±0.1$^c$ | 1.0±0.03$^a$ |

The data are presented as means ±SE calculated from three replicates.

Different letters refer to significant differences at ($P<0.05$).

### 3. Effect of gum Arabic and *Boswellia* sp. on the blood electrolytes in the rats affected with ARF induced by glycerol or paracetamol.

Data presented in **Tables (2 & 3)** indicate the effect of gum Arabic and *Boswellia sp*. on the blood electrolytes (potassium, calcium, sodium, chloride and bicarbonate) analyzed at the end of experiment period (30 days) in the rats affected with ARF induced by glycerol or paracetamol. The data indicated significant (P<0.05) increases in the levels of potassium for the rats treated with glycerol and paracetamol in the positive controls (5.2 ± 0.2 & 4.8 ± 0.1 mmol/L, respectively) compared to the negative control group (3.7 ± 0.1 mmol/L). This symptom is called hyperkalemia which may be due to the retention of potassium ($K^+$) in the blood owing to renal dysfunction. The data also indicated significant (P<0.05) decreases in the levels of calcium for the rats treated with glycerol and paracetamol in the positive control groups (0.5 ± 0.04 & 0.5 ± 0.03 mmol/L, respectively) compared to the negative control group (1.1±0.02 mmol/L). This symptom is called hypocalcemia which may be due to the decrease of calcitriol hormone in the blood owing to kidney damage. Data presented in **Table (3)** indicated significant (P<0.05) increases in the levels of sodium for the rats treated with glycerol and paracetamol in the positive control groups (155 ± 0.8 & 153 ± 1.8 mmol/L, respectively) compared to the negative control group (135 ± 0.8 mmol/L). This may be attributed to the retention of sodium ($Na^+$) in the blood owing to renal dysfunction. Initially, ARF is characterized by decrease of blood sodium owing to increase of its excretion in the urine. After that, the decrease of blood sodium leads to decrease of blood pressure which stimulates the kidneys to increase the secretion of renin enzyme. This enzyme leads to increase of angiotensin hormone in the blood (renin-angiotensin system). This hormone leads to increase of aldosterone hormone which promotes sodium retention. The data also indicated significant (P<0.05) increases in the levels of chloride for the rats treated with glycerol and paracetamol in the positive control groups (124 ± 0.8 & 125±0.8 mmol/L, respectively) compared to the negative control group (104 ± 0.8 mmol/L). Data presented in the same table indicated significant (P<0.05) decreases in the levels of bicarbonate for the rats treated with glycerol and paracetamol in the positive control groups (17±1.3 & 18±1.0 mmol/L, respectively) compared to the negative control group (25±0.7 mmol/L). The therapeutic effects of both plants against ARF induced by both compounds were observed as indicated by restoring the levels of these electrolytes to their normal ranges. These results are in agreement with those obtained by **Abeloff (2000); Ibrahim (2014) and Abdulmumin et al (2014)**.

**Table 3.** Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the blood sodium, chloride and bicarbonate in the rats affected with ARF induced by glycerol or paracetamol.

| Treatments | Sodium (mmol/L) | Chloride (mmol/L) | Bicarbonate (mmol/L) |
|---|---|---|---|
| Control | 135±0.8[b] | 104±0.3[b] | 25±0.7[a] |
| Glycerol | 155±0.8[a] | 124±0.5[a] | 17±1.3[b] |
| Glycerol+ G.A. | 138±1.4[b] | 113±0.6[b] | 22±0.8[a] |
| Glycerol + B.S | 136±0.8[b] | 111±0.7[b] | 21±1.7[a] |
| Paracetamol | 153±1.8[a] | 125±0.8[a] | 18±1.0[b] |
| Paracetamol + G.A | 138±0.8[b] | 111±1.4[b] | 22±1.6[a] |
| Paracetamol + B.S | 137±1.4[b] | 110±0.5[b] | 23±0.6[a] |

The data are presented as means ±SE calculated from three replicates.
Different letters refer to significant differences at (P<0.05).

### 4. Effect of gum Arabic and *Boswellia* sp. on the blood glucose in the rats affected with ARF induced by glycerol or paracetamol.

**Table (4)** illustrates the effect of gum Arabic and *Boswellia sp*. on the blood glucose analyzed at the end of experiment in the rats affected with ARF induced by glycerol or paracetamol. The results illustrated significant (P<0.05) decreases in the levels of blood glucose for the rats treated with glycerol and paracetamol in the positive control groups (67±3.3 & 66±2.0 mg/dl, respectively) compared to the negative control group (97±1.4 mg/dl). This symptom is called hypoglycemia which may be ascribed to the accumulation of insulin hormone in the blood owing to renal dysfunction. The remedial effects of both plants against ARF induced by both compounds were observed as indicated by restoring the levels of this parameter to its normal range.

**Table 4.** Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the blood glucose in the rats affected with ARF induced by glycerol or paracetamol

| Treatments | Glucose (mg/dl) |
|---|---|
| Control | 97±1.4[a] |
| Glycerol | 67±3.3[b] |
| Glycerol+ G.A. | 106±1.3[a] |
| Glycerol + B.S | 102±1.2[a] |
| Paracetamol | 66±2.0[b] |
| Paracetamol + G.A | 105±3.0[a] |
| Paracetamol + B.S | 104±3.5[a] |

The data are presented as means ±SE calculated from three replicates.

Different letters refer to significant differences at (P<0.05).

### 5. Effect of gum Arabic and *Boswellia* sp. on the liver profile in the rats affected with ARF induced by glycerol or paracetamol.

Data presented in **Tables (5 & 6)** elucidate the effect of gum Arabic and *Boswellia* aqueous solutions on the liver profile such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), total bilirubin, total protein and albumin analyzed at the end of experiment period (30 days) in the rats affected with ARF induced by glycerol or paracetamol. The rats treated with paracetamol in the positive control group recorded significant (P<0.05) increases in the levels of serum total bilirubin (1.7 ± 0.09 mg/dl), AST (101 ± 2.4 U/L) and ALT (57 ± 1.7 U/L) while the rats treated with glycerol in the other positive control group did not record these increases but they exhibited these parameters in their normal ranges (0.4 ± 0.06 mg/dl, 46 ± 5.6 and 23 ± 2.7 U/L, respectively) compared to the negative control group (0.3 ± 0.06 mg/dl, 40 ± 1.4 and 21 ± 1.1 U/L, respectively). It means that paracetamol caused liver injury besides kidney injury as indicated by increasing the levels of serum liver enzymes (AST & ALT) and total bilirubin. It can be noticed that glycerol as ARF inducer was more effective and more specific than paracetamol as indicated by kidney function tests and liver function tests. The remedial effects of both plants against liver damage induced by paracetamol were observed as indicated by restoring the levels of serum liver enzymes (AST & ALT) and total bilirubin to their normal values. No significant (P<0.05) changes in the levels of serum liver enzymes (AST & ALT) and total bilirubin were observed for the rats treated with glycerol and both plants compared to the negative control group. These results are in accordance with those obtained by **Reddy et al (2012)**. Data presented in **Table (6)** elucidated significant (P<0.05) decreases in the levels of serum total protein for the rats treated with glycerol and paracetamol in the positive controls (5.2 ± 0.2 & 5.2 ± 0.2 g/dl, respectively) compared to the negative control (7.2 ± 0.1 g/dl). The data also elucidated significant (P<0.05) decreases in the levels of serum albumin for the rats treated with glycerol and paracetamol in the positive control groups (2.5±0.2 & 2.5±0.2 g/dl, respectively) compared to the negative control (4.4±0.1 g/dl). Decreasing the levels of serum total protein and albumin for both positive control groups compared to the negative control group may be due to the excretion of albumin in the urine owing to kidney damage.

**Table 5.** Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the liver profile (total bilirubin, AST and ALT) in the rats affected with ARF induced by glycerol or paracetamol.

| Treatments | Total billirubin (mg/dl) | AST (U/L) | ALT (U/L) |
|---|---|---|---|
| Control | 0.3±0.06[b] | 40±1.4[b] | 21±1.1[b] |
| Glycerol | 0.4±0.06[b] | 46±5.6[b] | 23±2.7[b] |
| Glycerol+ G.A. | 0.5±0.09[b] | 39±2.6[b] | 20±1.5[b] |
| Glycerol + B.S | 0.4±0.09[b] | 39±2.3[b] | 20±1.2[b] |
| Paracetamol | 1.7±0.09[a] | 101±2.4[a] | 57±1.7[a] |
| Paracetamol + G.A | 0.5±0.06[b] | 40±3.6[b] | 24±2.1[b] |
| Paracetamol + B.S | 0.5±0.06[b] | 40±1.7[b] | 22±1.2[b] |

The data are presented as means ±SE calculated from three replicates.

Different letters refer to significant differences at (P<0.05).

It is also observed that the levels of serum total protein and albumin for the rats treated with both plants increased significantly (P<0.05) compared to the positive control groups to approach those in the negative control group. The therapeutic effects of both plants against ARF induced by both compounds were observed as indicated by increasing the levels of serum total protein and albumin after decreasing of them. These results are in conformity with those obtained by **Kondaa et al (2015)**.

**Table 6.** Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the liver profile (total protein and albumin) in the rats affected with ARF induced by glycerol or paracetamol.

| Treatments | Total protein (g/dl) | Albumin (g/dl) |
|---|---|---|
| Control | 7.2±0.1[a] | 4.4±0.1[a] |
| Glycerol | 5.2±0.2[c] | 2.5±0.2[b] |
| Glycerol+ G.A. | 6.5±0.1[b] | 3.6±0.1[a] |
| Glycerol + B.S | 6.6±0.1[b] | 3.6±0.1[a] |
| Paracetamol | 5.2±0.2[c] | 2.5±0.2[b] |
| Paracetamol + G.A | 6.6±0.1[b] | 3.6±0.1[a] |
| Paracetamol + B.S | 6.7±0.1[b] | 3.7±0.1[a] |

The data are presented as means ±SE calculated from three replicates.
Different letters refer to significant differences at (P<0.05).

### 6. Effect of gum Arabic and *Boswellia* on the hematological analyses in the rats affected with ARF induced by glycerol or paracetamol.

Data presented in **Tables (7 & 8)** demonstrate the effect of gum Arabic and *Boswellia* on the hematological analyses such as hemoglobin (Hb) concentration, hematocrit (Hct) percentage, red blood cells (RBCs), white blood cells (WBCs) and platelets (PLTs) counts analyzed in the rats affected with ARF induced by glycerol or paracetamol. The data demonstrated significant (P<0.05) decreases in the levels of hemoglobin for the rats treated with glycerol and paracetamol in the positive control groups (10 ± 0.1 & 10 ± 0.2 g/dl, respectively) compared to the negative control group (14 ± 0.3 g/dl). This symptom is called anemia which may be ascribed to the decrease of erythropoietin hormone in the blood owing to kidney damage. The data also demonstrated significant (P<0.05) decreases in the levels of hematocrit for the rats treated with glycerol and paracetamol in the positive control groups (35 ± 1.4 & 32 ± 3.0 %, respectively) compared to the negative control group (42 ± 3.3 %). Data presented in **Table (8)** demonstrated significant (P<0.05) decreases in the levels of RBCs for the rats treated with glycerol and paracetamol in the positive control groups (4.2±0.3 & 4.2±0.7 x$10^6$/µl, respectively) compared to the negative control group (5.6 ± 0.4 x$10^6$/µl). The curative effects of both plants against ARF induced by both compounds were observed as indicated by increasing the levels of these parameters after decreasing of them. No significant (P<0.05) changes in the levels of WBCs and PLTs were noticed for all treatments compared to the positive and negative controls. These results are in agreement with those obtained by **Adeneye et al (2008) and Omer et al (2013)**.

**Table 7**. Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the hematological analyses (hemoglobin and hematocrit) in the rats affected with ARF induced by glycerol or paracetamol.

| Treatments | Hemoglobin (g/dl) | Hematocrit (%) |
|---|---|---|
| Control | 14±0.3[a] | 42±3.3[a] |
| Glycerol | 10±0.1[b] | 35±1.4[b] |
| Glycerol+ G.A. | 12±0.2[ab] | 39±1.6[ab] |
| Glycerol + B.S | 13±0.2[ab] | 38±1.2[ab] |
| Paracetamol | 10±0.2[b] | 32±3.0[b] |
| Paracetamol + G.A | 13±0.3[ab] | 38±1.5[ab] |
| Paracetamol + B.S | 12±0.2[ab] | 36±1.4[ab] |

The data are presented as means ±SE calculated from three replicates.
Different letters refer to significant differences at (P<0.05).

**Table 8.** Effect of gum Arabic (G.A) and *Boswellia sp*. (B.S) on the hematological analyses (RBCs, WBCs and PLTs) in the rats affected with ARF induced by glycerol or paracetamol.

| Treatments | RBCs (x$10^6$/µl) | WBCs (x$10^3$/µl) | PLTs (x$10^3$/µl) |
|---|---|---|---|
| Control | 5.6±0.4[a] | 7.7±0.9[a] | 258±36[a] |
| Glycerol | 4.2±0.3[b] | 7.1±1.2[a] | 237±27[a] |
| Glycerol+ G.A. | 4.4±0.2[b] | 7.2±1.4[a] | 222±24[a] |
| Glycerol + B.S | 4.6±0.7[b] | 7.4±0.4[a] | 258±25[a] |
| Paracetamol | 4.2±0.7[b] | 7.3±1.6[a] | 255±47[a] |
| Paracetamol + G.A | 4.5±0.2[b] | 7.5±1.5[a] | 247±57[a] |
| Paracetamol + B.S | 4.7±0.1[b] | 7.2±1.2[a] | 249±32[a] |

The data are presented as means ±SE calculated from three replicates.
Different letters refer to significant differences at (P<0.05).

Finally, the curative effects of gum Arabic and *Boswellia* sp. against ARF induced by glycerol or paracetamol were established as indicated by restoring the kidney function tests such as urea, creatinine, serum electrolytes and other parameters such as serum glucose, proteins and hematological indices to their normal values during the experiment period (30 days). The blood analyses also illustrated ARF symptoms such as increasing of urea and creatinine, hyperkalemia, hypocalcemia, hypoglycemia, blood acidosis and anemia occurring in the positive control groups, and recovery of these symptoms in the treated rats with both plants. The therapeutic effects of both plants against ARF may be due to their antioxidant and/or anti-inflammatory activity.

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