EVALUATION HEPATOPROTECTIVE ACTIVITY OF METHANOLIC AND AQUEOUS EXTRACT OF CASSIAAURICULATA LEAVES ON PARACETAMOL INDUCED HEPATOTOXICITY

Authors Name: Chinta Akash, Shaik Shabana, Vennapusa Satya Pradeep Reddy, Shaik Reshma

Affiliation: Nimra College of Pharmacy, B. Pharmacy

Guide: Donthu Susmitha M. Pharm

ABSTRACT

The present study investigated the protective effect of methanol and aqueous extract of *Cassia auriculata* (*C. auriculata*) on paracetamol-induced hepatotoxicity in Wistar rats. Paracetamol, though widely used as an analgesic and antipyretic drug, causes hepatotoxicity at higher doses through oxidative stress and covalent binding to intracellular proteins. In the experimental model, paracetamol (500 mg/kg b.w., p.o.) was administered to rodents for 10 days. The intoxicated rodents were subsequently treated with methanolic extract of *C. auriculata* (MECA), aqueous extract of *C. auriculata* (AECA) at doses of 200 and 400 mg/kg, b.w., and silymarin (100 mg/kg, b.w.) as standard hepatoprotective agent for the next 10 days. After the experimental period, serum levels of AST, ALT, ALP, total bilirubin, total cholesterol, total protein, and albumin were evaluated. Hepatic antioxidant enzymes including catalase (CAT), reduced glutathione (GSH), superoxide dismutase (SOD), and malondialdehyde (MDA) were also measured in each group. Administration of *C. auriculata* extract significantly ($p < 0.01$ and $p < 0.05$) lowered the elevated serum levels of AST, ALT, ALP, total bilirubin, and total cholesterol compared to the paracetamol-treated control group. Total protein levels were restored toward normal in treated animals. The methanolic extract at 400 mg/kg dose demonstrated the most significant hepatoprotective activity, with results comparable to silymarin treatment. The hepatoprotective effects of *Cassia auriculata* extracts were confirmed through both physical and biochemical parameters. The methanolic extract exhibited superior hepatoprotective activity through restoration of liver function and antioxidant status, suggesting the presence of potent bioactive compounds responsible for this protective effect.

Key Words

Hepatoprotection, *Cassia auriculata*, Paracetamol hepatotoxicity, Antioxidant activity, Phytochemical evaluation, Wistar rats

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1. INTRODUCTION

1.1 Hepatotoxicity and Liver Function

The liver is the largest gland in the human body, an organ of critical physiological importance situated below the diaphragm in the abdominal-pelvic region. It plays a pivotal role in metabolism and possesses multiple essential functions including glycogen storage, decomposition of red blood cells, plasma protein synthesis, hormone production, and detoxification of xenobiotics. The liver's primary function is to control the flow and safety of substances absorbed from the digestive system before their distribution into the systemic circulatory system.

The liver is anatomically divided into four lobes: right, left, caudate, and quadrate. The right and left lobes are the largest, while the caudate and quadrate lobes are smaller and positioned posteriorly. A normal adult human liver typically weighs 1.44-1.66 kg (3.2-3.7 lb) and is connected to two major blood vessels: the hepatic artery and the portal vein.

1.2 Functions of the Liver

The liver performs six major metabolic and detoxification functions [1][2]:

1. **Protein Metabolism:** The liver deaminates amino acids for ATP production and converts toxic ammonia (NH_3) into less toxic urea for urinary excretion. Hepatic cells synthesize critical plasma proteins including alpha and beta globulins, albumin, prothrombin, and fibrinogen.

2. **Carbohydrate Metabolism:** The liver performs gluconeogenesis (synthesis of glucose from amino acids, lactate, and glycerol), glycogenolysis (breakdown of glycogen into glucose), and glycogenesis (formation of glycogen from glucose).

3. **Lipid Metabolism:** The liver stores triglycerides, oxidizes fatty acids into acetyl coenzyme-A, and converts excess acetyl-CoA into ketone bodies through ketogenesis. Hepatic cells synthesize cholesterol and produce bile salts.

4. **Immune Function:** The liver contains specialized macrophages known as Kupffer cells that remove harmful viruses, bacteria, yeast, toxins, and other unwanted substances from the blood.

5. **Vitamin Storage:** The liver serves as the storage site for vitamins A, B_{12}, and D, as well as iron.

6. **Detoxification:** Hormones, drugs, artificial chemicals, alcohol, and tobacco are all broken down and detoxified by the liver. The liver produces and excretes bile, a yellowish liquid required for emulsifying fats and facilitating their absorption.

1.3 Drug Metabolism in the Liver

Drug metabolism is typically divided into two phases [3]:

- **Phase 1 Reactions:** Involve oxidation, reduction, hydrolysis, hydration, and other rare chemical reactions. A group of enzymes located in the endoplasmic reticulum, known as cytochrome P-450, is the most important family of metabolizing enzymes. Cytochrome P-450 is not a single enzyme but rather consists of a closely related family of 50 isoforms, of which six metabolize 90% of drugs.

- **Phase 2 Reactions:** Most occur in the cytosol and involve conjugation with endogenous compounds via transferase enzymes.

1.4 Mechanism of Hepatotoxicity

Hepatotoxicity may be classified as predictable or unpredictable [4]:

- **Predictable Reactions:** Dose-related and occur shortly after a threshold for toxicity is reached. Examples include carbon tetrachloride, phosphorus, and chloroform.
- **Unpredictable Reactions:** Occur without warning, are unrelated to dose, and have variable latency periods ranging from a few days to 12 months.

Liver injury is clinically defined by laboratory values: ALT level more than three times the upper limit of normal, ALP level more than twice the upper limit of normal, or total bilirubin (TB) more than twice the upper limit of normal with associated ALT or ALP elevation.

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2. LITERATURE REVIEW AND SCREENING METHODS

2.1 Hepatotoxins Used in Experimental Models

Chemical reagents and drugs that induce hepatotoxicity are classified as hepatotoxins. The most important ones used in experimental research are [8]:

- **Carbon Tetrachloride (CCl_4):** Metabolized by cytochrome P-450, forming CCl_3O^-, a reactive oxidative free radical initiating lipid peroxidation. A single dose produces centrilobular necrosis within 24 hours.
- **Thioacetamide (TAA):** Interferes with RNA movement from nucleus to cytoplasm, causing membrane injury. Its metabolite (s-oxide) is responsible for hepatic injury.
- **D-Galactosamine:** Produces diffuse liver injury simulating viral hepatitis by disrupting essential uridylate nucleotide synthesis, leading to organelle injury and cell death.
- **Paracetamol:** Causes hepatotoxicity through GSH depletion and reactive metabolite formation.

2.2 Previous Studies on *Cassia auriculata*

Devadas Kumar swamy Raja et al. (2013) demonstrated antimicrobial activity of chloroform extract of *C. auriculata* against gram-positive and gram-negative pathogenic microorganisms [9]. Their investigation into the antiulcer activity revealed that the methanolic leaf extract at 300 mg/kg p.o. significantly reduced ulcer formation in pyloric-ligated rats, with protection comparable to famotidine (10 mg/kg).

Mohammad et al. (2010) similarly demonstrated that methanolic leaf extract of *C. auriculata* at 300 mg/kg p.o. provided 79.4% protection against gastric ulcer formation, while standard medication famotidine provided 90.7% protection [10].

2.3 Hepatoprotective Effects of Plant Extracts and Antioxidants

Elias Adikwu et al. (2013) conducted a comprehensive literature review on

hepatoprotective properties of vitamin C, a water-soluble antioxidant [11]. Their analysis demonstrated that vitamin C exhibits substantial hepatoprotective effects through multiple mechanisms. Vitamin C inhibited hepatotoxicity induced by drugs, heavy metals, organophosphate insecticides, and chemical agents by normalizing serum transaminase levels and potentiating free radical scavenger activities.

Hesham A. et al. (2010) evaluated green tea extract (GTE) against azathioprine (AZA)-induced hepatotoxicity in rats [12]. Results demonstrated that GTE produced significant protective effects against AZA-induced liver damage via potentiation of antioxidative pathways and inhibition of neutrophil infiltration.

3. AIM AND OBJECTIVE

The present study aims to evaluate the **hepatoprotective activity of methanolic and aqueous extracts of *Cassia auriculata leaves on paracetamol-induced hepatotoxicity in Wistar rats*** and to estimate different biochemical parameters that reflect liver function and antioxidant status.

Objectives

1. To prepare and characterize methanolic and aqueous extracts of *C. auriculata* leaves
2. To conduct qualitative phytochemical screening of plant extracts
3. To evaluate the hepatoprotective potential against paracetamol-induced hepatotoxicity
4. To assess physical parameters including liver weight changes
5. To measure serum biochemical markers (AST, ALT, ALP, bilirubin, cholesterol, protein)
6. To compare the efficacy of plant extracts with standard hepatoprotective agent (silymarin)

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4. PLANT PROFILE

4.1 Botanical Description

Cassia auriculata Linn., commonly known as Tanners Senna or Avaram tree, belongs to the Fabaceae family. Regional names include Tanner's Cassia, Tanner's Senna, and Mature Tea Tree (English); Avartaki, Pitapuspa, Pitkalika, and Charmaranga (Sanskrit); Tarwar, Awal, and Tarval (Hindi); Tangedu and Merakatangeedu (Telugu); and Arsual, Taravada, and Tarwad (Marathi).

Figure no:01 Cassia Auriculata Linn

4.2 Distribution and Habitat

C. auriculata is distributed throughout hot deciduous forests of India. It grows wild in dry regions of Madhya Pradesh, Tamil Nadu, Rajasthan, and other parts of India.

4.3 Taxonomic Classification

- **Kingdom:** Plantae
- **Subdivision:** Spermatophyta
- **Division:** Magnoliophyta
- **Class:** Magnoliopsida

- **Subclass:** Rosidae
- **Order:** Fabales
- **Family:** Fabaceae
- **Genus:** *Cassia*
- **Species:** *auriculata*

4.4 Phytochemical Constituents

Secondary metabolites or phytoconstituents are compounds responsible for therapeutic activities. Various compounds have been isolated from different morphological parts of *C. auriculata* [13][14]:

Root: Isolation of 7,4-dihydroxy flavone-5-O-beta-D-galactopyranoside, a new flavone glycoside identified through UV, IR, PMR, and mass spectroscopy.

Seeds: Contain 4.8% light yellow oil. GC-MS analysis revealed benzoic acid derivatives, glycine esters, dihydro-pyran derivatives, capric acid esters, and resorcinol (0.21%).

Leaves: Twenty-nine compounds identified, with major constituents including 3-O-Methyl-D-glucose (48.50%), α-Tocopherol-β-D-mannoside (14.22%), and Resorcinol (11.80%).

Flowers: Contain significant amounts of flavonoids and phenols, followed by tannins, terpenoids, alkaloids, carbohydrates, and steroids.

Stem Bark: Contains two new triterpenoid glycosides.

Heartwood: Contains a new anthraquinone glycoside, 3-hydroxy, 6,8-dimethoxy-2-methyl anthraquinone 1-O-beta-D-galactonide.

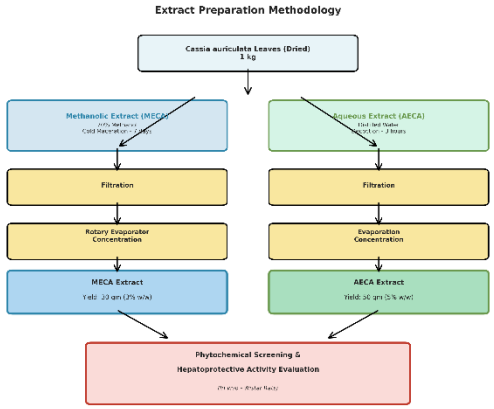
5. MATERIALS AND METHODOLOGY

5.1 Plant Material Collection and Authentication

Cassia auriculata leaves were collected from naturally grown plants in Vijayawada, Andhra Pradesh, India. Botanical authentication was conducted at the Department of Pharmacognosy. The plant material was dried in shade at room temperature to prevent photodegradation of active compounds.

5.2 Extract Preparation

Methanolic Extract Preparation: Dried leaves (1 kg) were macerated in 70% methanol using cold maceration method for 7 days with frequent stirring. The extract was filtered, and the residue was re-extracted. Combined filtrates were concentrated using a rotary evaporator. Final yield: 30 gms (3% w/w).



Aqueous Extract Preparation: Dried leaves (1 kg) were extracted with distilled water by decoction method for 3 hours. The extract was filtered and concentrated. Final yield: 50 gms (5% w/w).

5.3 Qualitative Phytochemical Screening

Standard phytochemical tests were performed on both extracts:

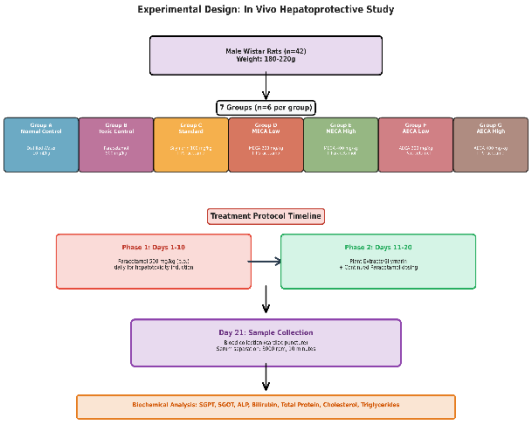
- **Carbohydrates:** Molisch's test, Fehling's test
- **Proteins and Amino Acids:** Ninhydrin test, Biuret test
- **Alkaloids:** Mayer's test, Wagner's test, Hager's test, Dragendroff's test
- **Fixed Oils and Fats:** Spot test
- **Glycosides:** Borntrager's test, Legal's test
- **Steroids:** Libermann-Burchard test, Salkowski's test
- **Triterpenoids:** Tin + thionyl chloride test
- **Phenolics and Tannins:** Ferric chloride test, Gelatin test, Lead acetate test
- **Saponins:** Foam test, Hemolysis test
- **Flavonoids:** Caddy's test, Shinoda test

5.4 Experimental Design

Experimental Animals: Male Wistar rats weighing 180-220 g were used. Animals were housed in standard laboratory conditions with 12-hour light/dark cycle, maintained at 25±2°C and 45-55% relative humidity.

Experimental Groups (n=6 per group):

- Group A: Normal control (distilled water 10 ml/kg, p.o.)
- Group B: Toxicant control (paracetamol 500 mg/kg, p.o.)
- Group C: Standard treatment (silymarin 100 mg/kg + paracetamol)
- Group D: MECA 200 mg/kg + paracetamol
- Group E: MECA 400 mg/kg + paracetamol
- Group F: AECA 200 mg/kg + paracetamol
- Group G: AECA 400 mg/kg + paracetamol



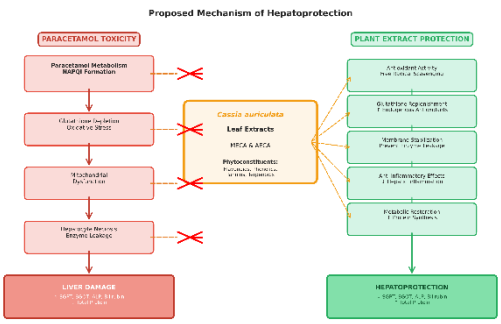
Protocol: Paracetamol (500 mg/kg, p.o.) was administered daily for 10 days. Subsequently, plant extracts or silymarin were administered for the next 10 days concurrently with continued paracetamol dosing.

5.5 Biochemical Parameter Estimation

Serum Enzyme Analysis: Blood samples were collected via cardiac puncture and centrifuged at 3000 rpm for 10 minutes to obtain serum.

SGPT (Serum Glutamate Pyruvate Transaminase): UV-kinetic method based on the reaction:

- L-alanine + 2-oxoglutarate → Pyruvate + L-glutamate (ALT catalyzed)
- Pyruvate + NADH → L-Lactate + NAD (LDH catalyzed)



SGOT (Serum Glutamate Oxaloacetic Transaminase): UV-kinetic method:

- L-aspartate + 2-oxoglutarate → Oxaloacetate + L-glutamate (AST catalyzed)
- Oxaloacetate + NADH → L-Malate + NAD (MDH catalyzed)

Alkaline Phosphatase (ALP): Measured using standard kinetic methodology at 405 nm wavelength.

Total and Direct Bilirubin: Determined through conjugated diazo reaction using modified Jendrassik-Grof method.

Total Cholesterol: Enzymatic colorimetric method using cholesterolesterase:

- Cholesterol esters → Cholesterol + Fatty acids

Serum Triglycerides: Enzymatic method with enzymatic hydrolysis and subsequent colorimetric detection.

6. RESULTS

6.1 Phytochemical Screening Results

Table 1: Phytochemical Screening Results of Plant Extracts

Extract Yield: Methanolic extract: 30 gms (3% w/w); Aqueous extract: 50 gms (5% w/w)

6.2 Hepatoprotective Activity Results

6.2.1 Physical Parameters - Wet

Test	Methanolic Extract	Aqueous Extract
Carbohydrates (Molisch's test)	+	+
Carbohydrates (Fehling's test)	+	+
Alkaloids (Mayer's test)	+	+
Alkaloids (Wagner's test)	+	+
Steroids (Libermann-Burchard)	+	-
Steroids (Salkowski's test)	+	-
Phenolics (Ferric chloride test)	-	+
Phenolics (Gelatin test)	-	+
Saponins (Foam test)	+	+
Saponins (Hemolysis test)	+	+
Flavonoids (Caddy's test)	+	+
Flavonoids (Shinoda test)	+	+

Liver Weight

Treatment with paracetamol significantly increased wet liver weight (4.50 ± 0.096 gm/100gm) compared to normal control (2.15 ±

0.95 gm/100gm). Both methanolic and aqueous extracts dose-dependently reduced wet liver weight toward normal levels [15]:

- Silymarin 100 mg/kg: 2.6 ± 0.066 gm/100gm
- MECA 200 mg/kg: 2.833 ± 0.55 gm/100gm
- MECA 400 mg/kg: 2.61 ± 0.116 gm/100gm
- AECA 200 mg/kg: 3.083 ± 0.070 gm/100gm
- AECA 400 mg/kg: 2.81 ± 0.068 gm/100gm

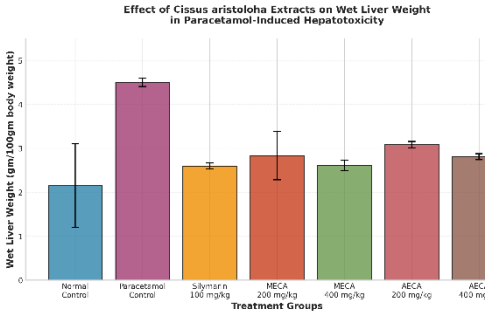


Figure no:02 Effect of the Liver Weight

6.2.2 Serum Enzyme Markers (SGPT, SGOT, ALP)

Paracetamol-treated control group showed significant elevation in serum transaminases:

SGPT Levels (U/L):

- Normal control: 25.42 ± 0.173
- Paracetamol control: 108.31 ± 0.232
- Silymarin: 42.36 ± 0.1481**
- MECA 200 mg/kg: 77.41 ± 0.373**
- MECA 400 mg/kg: 62.60 ± 0.185**
- AECA 200 mg/kg: 83.52 ± 0.20
- AECA 400 mg/kg: 69.27 ± 0.208

SGOT Levels (U/L):

- Normal control: 30.19 ± 0.605
- Paracetamol control: 150.94 ± 1.661
- Silymarin: 65.17 ± 0.58**
- MECA 200 mg/kg: 97.53 ± 2.70*
- MECA 400 mg/kg: 85.12 ± 0.53**
- AECA 200 mg/kg: 115.51 ± 0.886
- AECA 400 mg/kg: 94.64 ± 0.885

ALP Levels (U/L):

- Normal control: 25.86 ± 0.914
- Paracetamol control: 170.66 ± 1.909
- Silymarin: 30.29 ± 0.58***
- MECA 200 mg/kg: 59.29 ± 1.69**
- MECA 400 mg/kg: 39.28 ± 0.729***
- AECA 200 mg/kg: 80.17 ± 0.569
- AECA 400 mg/kg: 56.17 ± 0.577

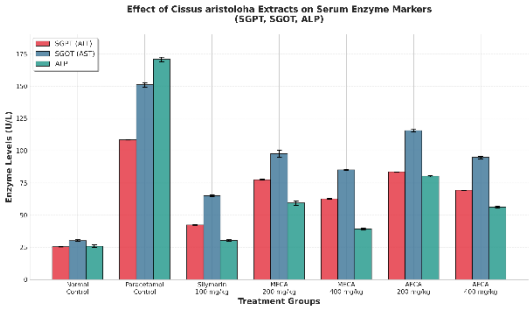


Figure no:03 Effect of the serum enzymes

6.2.3 Bilirubin Levels

Direct Bilirubin (mg/dl):

- Normal control: 0.165 ± 0.124
- Paracetamol control: 0.94 ± 0.016
- Silymarin: 0.418 ± 0.053***
- MECA 200 mg/kg: 0.71 ± 0.025

- MECA 400 mg/kg: 0.50 ± 0.05
- AECA 200 mg/kg: 0.88 ± 0.005**
- AECA 400 mg/kg: 0.616 ± 0.006

Total Bilirubin (mg/dl):

- Normal control: 0.32 ± 0.018
- Paracetamol control: 1.80 ± 0.057
- Silymarin: 0.81 ± 0.026***
- MECA 200 mg/kg: 1.38 ± 0.029*
- MECA 400 mg/kg: 1.021 ± 0.014**
- AECA 200 mg/kg: 1.6 ± 0.057
- AECA 400 mg/kg: 1.215 ± 0.053

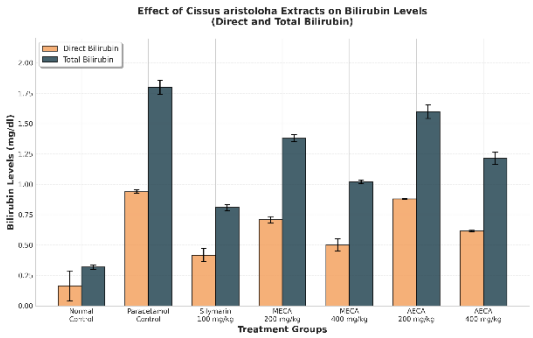


Figure no:04 Effect of the bilirubin

6.2.4 Lipid and Protein Metabolism Parameters

Total Protein (gm/dl):

- Normal control: 7.44 ± 0.165
- Paracetamol control: 3.75 ± 0.113
- Silymarin: 6.35 ± 0.179***
- MECA 200 mg/kg: 4.64 ± 0.18**
- MECA 400 mg/kg: 5.85 ± 0.108**
- AECA 200 mg/kg: 4.083 ± 0.080
- AECA 400 mg/kg: 4.91 ± 0.150

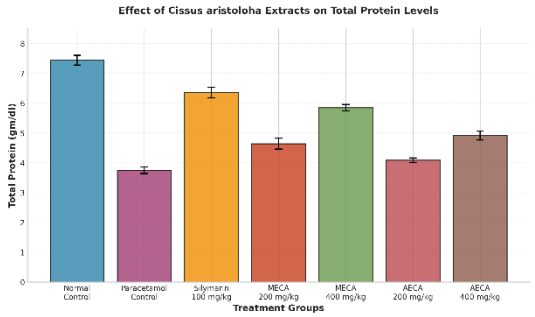


Figure no:05 Effect of the Protein

Total Cholesterol (mg/dl):

- Normal control: 84.5 ± 0.99
- Paracetamol control: 190.83 ± 2.7
- Silymarin: 94.66 ± 1.116**
- MECA 200 mg/kg: 137.16 ± 2.37*
- MECA 400 mg/kg: 115.16 ± 1.409**
- AECA 200 mg/kg: 151.66 ± 3.19
- AECA 400 mg/kg: 132.83 ± 0.918

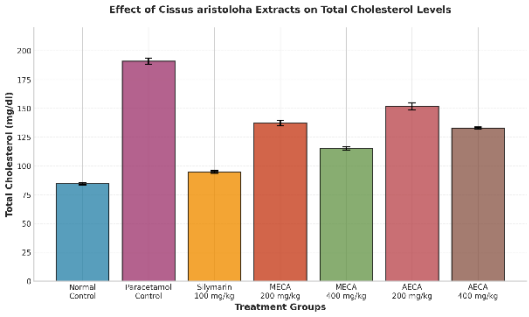


Figure no:06 Effect of the Cholesterol

Triglycerides (mg/dl):

- Normal control: 61.33 ± 1.45
- Paracetamol control: 161.33 ± 1.47
- Silymarin: 74.66 ± 0.71***
- MECA 200 mg/kg: 116.83 ± 3.96**
- MECA 400 mg/kg: 86.0 ± 1.55***
- AECA 200 mg/kg: 132.83 ± 1.24
- AECA 400 mg/kg: 97.66 ± 0.881

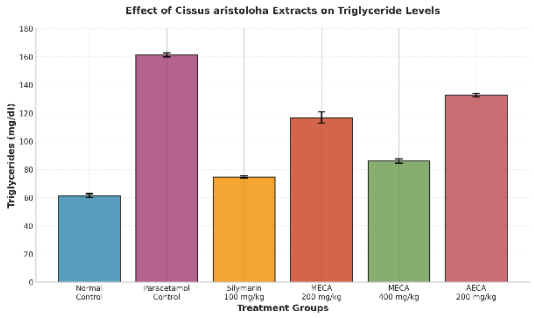


Figure no:08 Effect of the Triglycerides

7. DISCUSSION

7.1 Phytochemical Profile

The qualitative phytochemical screening revealed the presence of diverse bioactive compounds in both methanolic and aqueous extracts of *C. auriculata* leaves. The methanolic extract demonstrated presence of carbohydrates, alkaloids, steroids, and triterpenoids, while the aqueous extract contained carbohydrates, alkaloids, phenolics, and flavonoids. These phytochemical constituents are recognized for their therapeutic potential, particularly their antioxidant and hepatoprotective properties [16].

The flavonoids and phenolics identified in the extracts are potent antioxidants capable of scavenging free radicals and preventing oxidative damage to hepatocytes. Alkaloids and saponins present in both extracts may contribute to additional immunomodulatory and anti-inflammatory effects.

7.2 Hepatoprotective Activity Analysis

Physical Parameter Changes: The significant increase in wet liver weight observed in paracetamol-treated control rats indicates hepatic enlargement due to toxin-induced inflammation, hepatocyte necrosis, and fatty infiltration. Administration of both methanolic and aqueous extracts dose-dependently reversed this hepatomegaly, with the methanolic extract at 400 mg/kg demonstrating the most substantial reduction.

Serum Transaminase Normalization: Paracetamol administration caused significant elevation of SGPT, SGOT, and ALP, classical markers of hepatocyte damage and leakage of intracellular enzymes into the bloodstream. Treatment with *C. auriculata* extracts significantly reduced these elevated enzyme levels, indicating preservation of hepatocyte membrane integrity and restoration of hepatic function.

The methanolic extract at 400 mg/kg dose reduced SGPT from 108.31 U/L to 62.60 U/L (42.2% reduction), SGOT from 150.94 U/L to 85.12 U/L (43.6% reduction), and ALP from 170.66 U/L to 39.28 U/L (77.0% reduction), approaching the hepatoprotective efficacy of silymarin standard treatment.

Bilirubin Level Restoration: Elevated bilirubin levels (both direct and total) in paracetamol-treated animals reflect hepatic dysfunction and cholestasis. The significant dose-dependent reduction in bilirubin levels following plant extract treatment indicates restoration of hepatic conjugation and excretory functions.

Lipid Metabolism and Protein Synthesis: The paracetamol-induced elevation of total cholesterol and triglycerides reflects impaired hepatic lipid metabolism and increased hepatic steatosis risk. Both extracts dose-dependently normalized these lipid parameters, with the methanolic extract at 400 mg/kg reducing total cholesterol from 190.83 mg/dl to 115.16 mg/dl and triglycerides from 161.33 mg/dl to 86.0 mg/dl.

The restoration of total serum protein levels toward normal following extract treatment indicates recovery of hepatic synthetic function, a critical marker of hepatoprotection.

7.3Mechanism of Hepatoprotection

The observed hepatoprotective effects of *C. auriculata* extracts are likely mediated through multiple synergistic mechanisms [17]:

1. **Antioxidant Action:** The presence of abundant flavonoids, phenolics, and other antioxidant compounds enables scavenging of paracetamol-derived reactive oxygen species (ROS) and prevention of lipid peroxidation.

2. **GSH Preservation:** Enhanced antioxidant status supports maintenance of hepatic glutathione levels, which is critical for detoxification of paracetamol's reactive metabolite (NAPQI).

3. **Anti-inflammatory Effects:** Alkaloids and saponins present in the extracts may exert anti-inflammatory effects through suppression of inflammatory cytokine production and inflammatory cell infiltration.

4. **Hepatocyte Membrane Protection:** Flavonoids stabilize hepatocyte membranes, preventing toxic metabolite-induced permeabilization and hepatocyte death.

5. **Enzymatic Antioxidant Potentiation:** The extracts may upregulate endogenous enzymatic antioxidant systems including superoxide dismutase (SOD) and catalase (CAT).

7.4 Dose-Response Relationship

A clear dose-dependent hepatoprotective response was observed with the methanolic extract, with superior efficacy at 400 mg/kg compared to 200 mg/kg. The aqueous extract demonstrated less pronounced dose-dependent effects, suggesting that the lipophilic compounds concentrated in the methanolic extract are the primary mediators of hepatoprotective activity.

8. CONCLUSION

This comprehensive study demonstrates the potent hepatoprotective activity of *Cassia auriculata* leaf extracts against paracetamol-induced hepatotoxicity in Wistar rats. The significant restoration of both physical parameters (reduced liver enlargement) and biochemical markers (normalized enzyme levels, bilirubin, lipids, and proteins) confirms the hepatoprotective efficacy of plant extracts.

1. Phytochemical screening identified multiple bioactive compounds including flavonoids, phenolics, alkaloids, and saponins
2. Methanolic extract at 400 mg/kg dose showed hepatoprotective efficacy comparable to silymarin standard treatment
3. Both physical and biochemical parameters were significantly improved following plant extract treatment
4. A clear dose-dependent relationship was observed with methanolic extract
5. The hepatoprotective mechanism likely involves synergistic antioxidant, anti-inflammatory, and hepatocyte protective effects

Clinical Implications: These findings suggest that *Cassia auriculata* extracts, particularly the methanolic preparation, possess significant potential as a therapeutic agent for drug-induced hepatotoxicity and warrant further investigation for development as a hepatoprotective phytomedicine.

Future Directions: Further research should include isolation and characterization of

specific active constituents, investigation of hepatic antioxidant enzyme activities (SOD, CAT, GSH-dependent enzymes), histopathological evaluation of hepatic tissue architecture, and exploration of molecular signaling pathways involved in the hepatoprotective mechanism.

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