Hepatoprotective Effects of Curcumin and Thymoquinone Against Chemically Induced Liver Injury: A Schematic Study with Meta-Analysis of Antioxidant and Anti-inflammatory Outcomes

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ABSTRACT

Background: Curcumin and thymoquinone are phytochemicals that have shown the ability to protect the liver in previous studies, with involvement of their antioxidant and anti-inflammatory activity. This study aimed to examine the effective concentrations of curcumin and thymoquinone at which liver injury could be mitigated by evaluating liver enzymes and markers of liver damage.

Methods: According to PRISMA 2020, this review and the diagram were created. Studies published up to 2025 were found in a thorough search of PubMed, Scopus, Web of Science, and the Cochrane Library. Included studies were experiments using animals that examined how curcumin and/or thymoquinone affected liver injury and led to changes in liver enzyme levels. Studies that were excluded were editorials, reviews, articles in languages other than English, conference abstracts, and those without any quantitative results. The OHAT Risk of Bias Rating Tool (Version January 2015) was used, and Odds ratios were used in a meta-analysis for the primary outcome, lowering of liver enzymes.

Results: Eleven studies were sampled. Meta-pooled analysis revealed that at a mean dose of 194.56 mg/kg (95% CI: 16.31-372.81), curcumin decreased liver enzymes at a significant level, whereas thymoquinone exhibited a significant effect at 27.99 mg/kg (95% CI: -7.6 to 63.59). Even though heterogeneity was high (I2 > 99%), sensitivity analysis was performed to show the robustness. The risk of bias was low to moderate, and evidence certainty was rated moderate as per GRADE.

Discussion: Liver damage is greatly reduced by curcumin and thymoquinone, mainly by lowering markers related to damaged cells in the liver. Nevertheless, restricted study designs and inconsistency of models indicated that future research should include standardized dosing as well as extended human studies.

Keywords: Curcumin, Thymoquinones, Chemical and Drug Induced Liver Injury, Liver diseases, Meta-Analysis, Antioxidants, Inflammation.

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INTRODUCTION

All over the world, liver damage is a major health issue that can come from contact with toxins, drugs, infections, or certain disorders of metabolism [1]. Since the liver is responsible for metabolism and removing toxins, it is easily affected by oxidative stress and inflammation, and these can lead to chronic liver issues and loss of function [2]. Treatments for liver damage are not always successful and can cause harm, which means it is necessary to find new and improved treatments [3].

Scientists have begun to focus on natural compounds that are antioxidants and anti-inflammatory agents for their potential benefits to the liver [4]. Curcumin from turmeric and thymoquinone from Nigella sativa are interesting because of their many biological effects [5]. Whether as singular ingredients or together, both compounds are known to solve oxidative damage, control inflammation, and take part in healing the liver in testing on common liver injuries [6].

To be protective, curcumin blocks lipid oxidation, works through the Nrf2/HO-1 (a type of antioxidant pathway), and lowers levels of pro-inflammatory cytokines [7]. Much like thymoquinone prevents damage to the liver by removing harmful free radicals, reducing the amount of pro-inflammatory cytokines, and stopping the activity of Nuclear Factor kappa B (NF-κB), which is essential for controlling inflammation [8]. Both agents have demonstrated liver protection in various models, like injuries caused by toxins and blood flow interruptions [9].

Problems with study design, variations in the amount used, length of treatment, and the animals involved make it hard to know if findings work for people [10]. Changes in how outcome measures are reported make comparisons of effects more difficult [11].

In this systematic review and meta-analysis, researchers focused on finding out how effective curcumin and thymoquinone concentrations were against experimental liver injury, particularly looking at liver enzyme levels as a marker of liver health.

METHODS

PRISMA Guidelines

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) 2020 guidelines [12].

The study used literature searches and structured techniques in PubMed, Scopus, Web of Science, and Cochrane Library to find articles up to the year 2025. For every database, the search strategies mention the Boolean operators (AND, OR), as well as filters and applied limits (such as availability only in English and only in full-text). The main keywords were: "curcumin", "thymoquinone", "liver injury", "hepatotoxicity", "oxidative stress", "inflammation", "biomarkers", and "animal model". Besides using the database, manual examination of reference lists from included studies was done to track down extra useful publications.

Inclusion and Exclusion Criteria

Research articles were only included if they were peer-reviewed original studies, tested curcumin and/or thymoquinone on chemically induced liver injury models (paracetamol, acrylamide, etc), analyzed antioxidants or anti-inflammatory markers as outcomes, and had full-text in English. The criterion for exclusion applied to: reviews, editorials, conference abstracts, case reports, duplicate records, or studies with missing or inappropriate biomarker data. The effective concentrations at which the curcumin and thymoquinone mitigated the liver injury markers were the primary focus of the study. While the level of Liver enzymes (ALT, AST, GSH, etc) affected by these compounds was studied as a secondary outcome.

Study Selection

Two reviewers worked separately, going through the titles, abstracts, and then full papers. Differences of opinion were settled through conversation with a further reviewer. All the relevant data were organized into a table using author/year, type of model, characteristics of the animals or samples, possible confounding factors, how much and how long curcumin or thymoquinone was given, and which outcomes were measured. Experts in the field were consulted when the information needed was unclear or missing.

Study Tools

The Risk of Bias Rating Tool from OHAT (Office of

Health Assessment and Translation) (January 2015 version) was applied to assess the possibility of bias in the studies. GRADE was also employed to review the quality and certainty of the available evidence and look at methodological diversity. Two people were responsible for conducting the evaluations separately, and a third stepped in if they disagreed. Automation tools were not used during the process of evaluating or choosing candidates.

Meta Analysis

An analysis combining study results was done for research reporting liver enzyme biomarker effects. Inverse variance weighted random effects models were applied to estimate 95% confidence intervals. The I^2 statistic was used to look for heterogeneity in data, and anything above 50% was taken to mean the heterogeneity was substantial. RevMan 5.4.1 was the software used for performing all the meta-analyses in this review. The concentrations of both curcumin and thymoquinone were taken as raw mean dosages (MRAW). A total of 6 in vivo studies on curcumin [13,14,15,16,17,18] and five in vivo studies on thymoquinone[19,20,21,22,23] were taken for meta-analysis. The findings were evaluated by omitting each study to check how sensitive they were to individual papers. For subgroup analysis the enzymatic markers and their levels were studied to verify the results of the meta-analysis.

A flow diagram in PRISMA format was used to show the process of selecting the studies, and results were summarized in organized tables and plots. There was no external funding, and no ethical approval was necessary since direct experiments with human or animal subjects were not done by the researchers.

RESULTS

A total of 222 studies were selected at an initial stage, from which 130 were duplicates and thus were removed at the first filtering step. After that, 92 studies were screened and 30 of them were removed on the basis of titles and content of abstract, which did not according to the criteria. 62 records were then further taken to the next step for full text screening, but full text downloadable data files were not retrievable for 22 studies, and therefore only 40 studies were screened by reviewers for full text. Out of these, some studies were of secondary data types, some lacked quantitative data, and some lacked evaluation of curcumin and thymoquinone; therefore, 11 studies were finally selected to be included in the study. You can see an illustration of study selection in **Figure 1**.

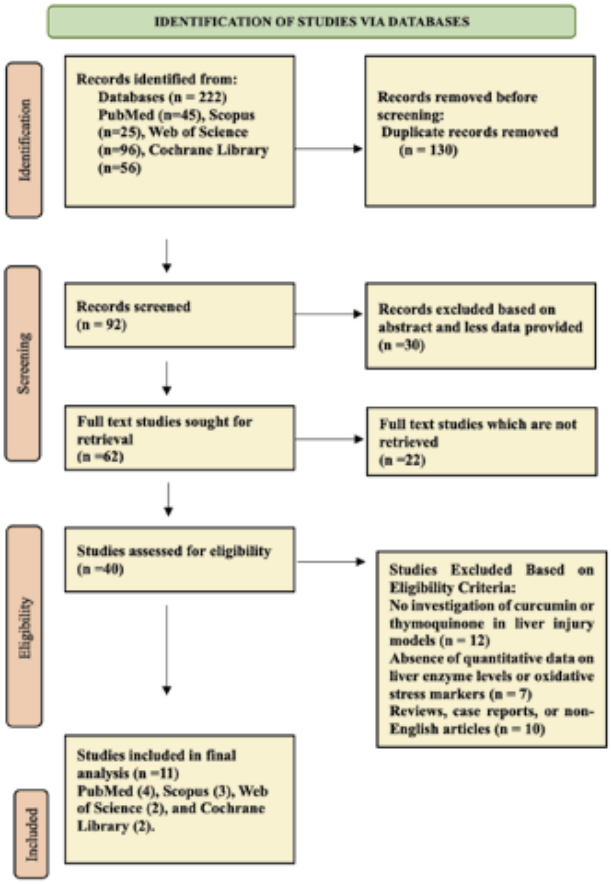

Figure 1: PRISMA flow diagram

The studies conducted on curcumin and thymoquinone were evaluated in various chemically induced liver injury models, such as paracetamol, acrylamide, methotrexate, aflatoxin B1, diazinon, heatstroke, and LPS/diclofenac. Rats and mice were the main animal models, and the number of animals in a group was between 5 to 10. The 77 animals used in curcumin studies and 41 thymoquinone studies added up to 118 total experimental animals. Doses ranged from 0.5 mg/kg to 500 mg/kg, orally or intraperitoneally. The duration of treatment was between 14 days and 28 days. Each of the studies had liver enzymes (ALT, AST), oxidative stress markers (MDA, GSH, SOD, CAT), and inflammatory mediators measured so that a quantitative synthesis of the results was possible. Key findings from in vivo studies on curcumin are summarized in Table 1.

Table 1: Summary of Characteristics and Effective Concentrations of Curcumin on Liver-Based Injuries

Source	Liver Injury Type	Animal Model	Sample Size (Control & Treated)	Curcumin Dose	Key Mechanisms of Hepatoprotection
Li et al., 2021	$HgCl_2$-induced	Mice	6 mice per group	50 mg/kg, oral	↓ALT, ↓AST, ↓inflammation, ↑Nrf2/HO-1, ↓CYP450s, trace element balance, apoptosis suppression.
Yang et al., 2024	Zearalenone-induced	BALB/c mice	n=10 for assays,	200 mg/kg	↓ALT/AST/ALP, ↓ROS, ↓MDA, ↓Caspase-3, Nrf2 normalization, inhibition of mitochondrial apoptosis.
Al-Dossari et al., 2020	LPS/Diclofenac-induced	Wistar rats	6 rats per group	200 mg/kg	↓CRP, ↓IL-6/TNF-α, ↑SOD/GSH, ↓NF-κB, ↓JNK/p38, ↑HO-1, antioxidant and anti-inflammatory effects.
Zhang et al., 2024	Aflatoxin B1-induced	Broiler chickens	80 chickens/group; n=10 per group for biochemical analysis	500 mg/kg	↑SOD, ↑GSH-Px, ↑CAT, ↑Nrf2/Keap1/HO-1/NQO1, ↓intestinal permeability, improved liver & gut histology.
Yang et al., 2024	Heatstroke-induced	Sprague-Dawley rats	40 per group	200 mg/kg	↓ALT/AST/LPS, ↓IL-6/TNF-α, ↓NF-κB/iNOS/ICAM-1, protected endothelial and hepatic structure.
Sunoqrot et al., 2024	Diclofenac-induced	BALB/c mice	5 per group	20 mg/kg (free CUR & nano-CUR)	CUR NPs > free CUR; ↓liver injury, ↓cyp2d9/ugt2b1, improved solubility & liver delivery via nanoencapsulation.

Table 2 highlights the characteristics of studies based on effective concentrations of thymoquinone on liver-based injury models

Table 2: Summary of characteristics and effective concentrations of thymoquinone (TQ) on liver-based injuries

Study	Liver Injury Model	Animal Model	Sample Size (per group)	TQ Dose & Duration	Biomarkers Measured	Hepatoprotective Effects
Abduh et al., 2023	Paracetamol-induced hepatotoxicity	Male Swiss rats	10 (Control), 10 (PAR), 10 (PAR+THYO)	0.5 mg/kg i.p. (nanoparticles), for 21 days	Liver enzymes (ALT, AST, ALP, GGT, LDH), bilirubin, lipid profile, oxidative stress (MDA, NO, GSH, SOD, CAT), immunological (IgG, IgM, TNF-α, ILs), apoptosis (Caspase-3, Bcl-2, Cytochrome C), gene expression	Restored liver enzymes, antioxidant levels, lipid profile, suppressed inflammation and apoptosis; normalized histopathology
Abdel-Daim et al., 2020	Acrylamide-induced oxidative liver injury	Male Wistar rats	8 (Control), 8 (AA), 8 (TQ10), 8 (TQ20)	10 or 20 mg/kg orally, for 21 days	Liver enzymes (ALT, AST, ALP), hepatic oxidative stress markers (MDA, NO, GSH, CAT, SOD), cytokines (IL-1β, IL-6, TNF-α), DNA damage (8-OHdG)	Normalized liver enzymes and antioxidant markers, reduced inflammatory cytokines and DNA damage
Wang et al., 2023	Hyperlipidemia-induced fatty liver injury	Male mice	8 (ND), 8 (HD), 8 (HD+TQ)	100 mg/kg/day by gavage, for 8 weeks	Lipid profile (TC, TG, LDL-C), liver enzymes (ALT, AST, ALP), histology, CD68, NLRP3, IL-1β, IL-18 (mRNA/protein), PI3K pathway	Reduced liver steatosis, inflammation, lipid accumulation; normalized ALT/AST
Danaei et al., 2022	Diazinon-induced hepatotoxicity	Male Wistar rats	8 per group (6 groups)	2.5, 5, 10 mg/kg/day orally for 28 days	ALT, AST, ALP, LDH, GSH, MDA, SOD, AChE, BChE, histopathology	Dose-dependent liver protection, reduced oxidative stress, improved ChE activity
Behairy et al., 2024	Methotrexate-induced liver injury	Male Wistar albino rats	7 per group	10 mg/kg/day orally, for 21 days (MTX on day 15)	ALT, AST, ALP, cholesterol, TG, LDL, HDL, MDA, GSH, SOD, CAT, TNF-α, Caspase-3, histology	Reversed liver toxicity, restored lipid and antioxidant profiles, decreased TNF-α and apoptosis

All these studies revealed that curcumin and thymoquinone were significant in inhibiting the effects of liver damage and oxidative stress caused by different toxic agents. Curcumin (200 mg/kg) restricted the increase in alanine aminotransferase (ALT) from 86.68 to 42.33 U/L and aspartate aminotransferase (AST) from 180.2 to 105.10 U/L, as well as elevated the antioxidant enzymes such as glutathione peroxidase (GSH-Px) from 206.1 to 358.3 U/mg in a zearalenone-induced liver injury model. Similarly, in acrylamide-induced injury,

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thymoquinone (20 mg/kg) minimized ALT to 27.20 U/L (initial 52.75) and AST to 65.37 U/L (initial 117.24), whereas GSH increased to 16.72 mg/L (initial 12.30). Thymoquinone administered in paracetamol-induced toxicity lowered ALT from 245.21 to 59.63 U/L, whereas the decrease in lipid peroxidation due to markers, such as MDA, was seen to be lowered by both compounds, e.g., 0.78-0.36 µmol/mL using curcumin, and 6.85-4.3 µmol/mL by administration of thymoquinone. These findings in various models supported that the two compounds significantly elevated liver enzymes and antioxidant levels, with high hepatoprotective effects.

A dose-dependent meta-analysis of effective concentrations of curcumin and thymoquinone in preclinical animal models of chemically mediated liver injury was carried out. Articles that found hepatoprotective effects in each of the compounds were chosen, and the raw mean dose (mg/kg) was separated and analyzed. A random-effects model was used to make two forest plots; one plot contained the six studies on curcumin, and a second plot incorporated the five research studies focusing on thymoquinone. The purpose of the analysis was to find out whether effective hepatoprotection was more likely to exist in lower, moderate, or high levels of these phytochemicals.

The meta-analysis of the effective dose of curcumin hepatoprotection included 6 studies consisting of 77 animal subjects. The pooled raw mean dose (MRAW) was 194.56 mg/kg (95% CI: 16.31-372.81) using a random-effects model with inverse variance weighting, which demonstrated a great discrepancy in effective concentrations. The significant heterogeneity was identified ($p < 0.01$), indicating that there were genuine variations between studies concerning liver injury models, the species of animals used, formulations, and treatment regimens ($I2 = 99.9\%$). Forest plots revealed that curcumin demonstrated efficacy in all studies included, but moderate to high doses (200 mg/kg) most frequently demonstrated hepatoprotective effects, with nanoformulations demonstrating efficacy even at lower concentrations (e.g., 20 mg/kg). Figure 2 depicts the forest plot showing effective concentrations of curcumin.

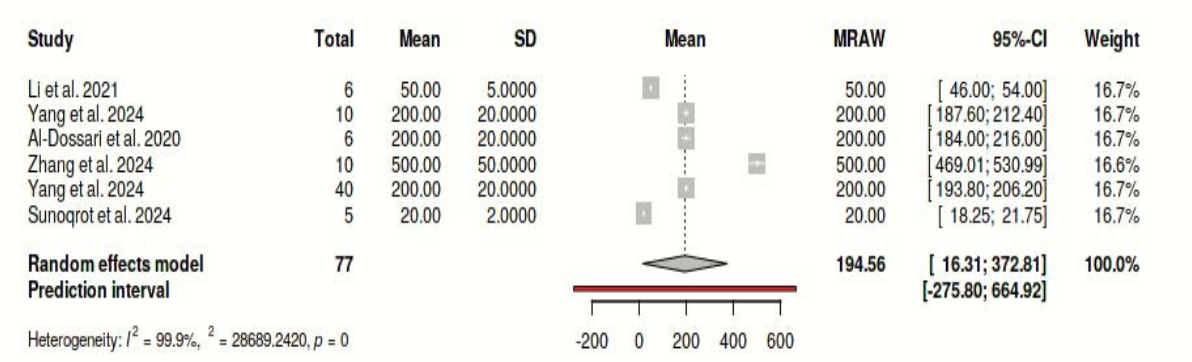

Figure 2: Forest Plot Depicting Effective Concentrations at Which Liver Injury Mitigation Was Observed Using Curcumin. The Left Side Depicts Lower Concentrations and The Right Side Depicts Higher Concentrations

In the meta-analysis of the effective dose of thymoquinone in hepatoprotection, five studies of 41 animal subjects were used. A random-effects model imposing inverse variance weight showed a pooled raw mean dose (MRAW) of 27.99 mg/kg (95% CI: -7.6 to 63.59), which revealed a broader range of similar efficacy concentrations and less consistent central tendency than that of curcumin. Substantial heterogeneity was observed ($p < 0.01$), with an I2 value of 99.8%, which indicated that heterogeneity didn't occur by chance; rather, variance in animal models, liver toxicity induction models, and other parameters contributed to it. All the studies showed hepatoprotective effects, and the effective dose was generally found to be in the range of 10-20 mg/kg, with even low concentrations (0.5 mg/kg) yielding positive results when nanoformulations were utilized, reflecting the strong effects of thymoquinone at low levels. Figure 3 highlights the effective concentrations of thymoquinone against liver injury.

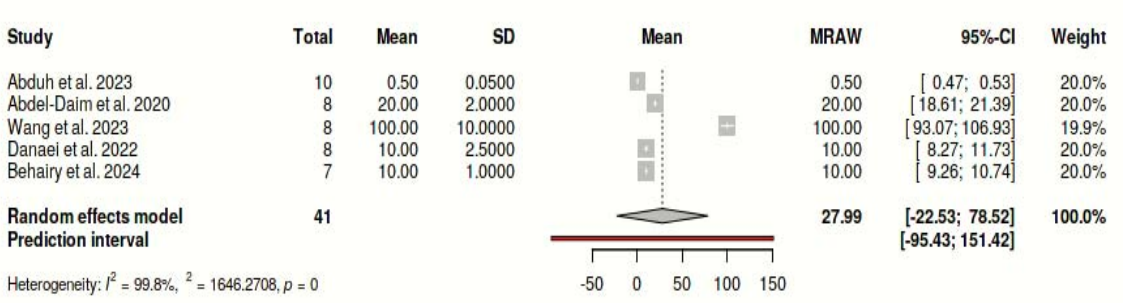

Figure 3: Forest Plot Depicting Effective Concentrations at Which Liver Injury Mitigation Was Observed Using Thymoquinone. The Left Side Depicts Lower Concentrations and The Right Side Depicts Higher Concentrations

In order to provide a better perception of the consistency of hepatoprotective effects, a subgroup analysis was conducted that focused on key biomarkers such as ALT, AST, and GSH, with malondialdehyde (MDA), superoxide dismutase (SOD), and catalase (CAT) considered as secondary outcomes. Curcumin was seen to significantly reduce the concentration of liver enzymes and oxidative stress markers across different types of injury models. In the zearalenone (ZEN) model, curcumin (200 mg/kg) reduced the ALT from 86.68 ± 6.94 U/L to 42.33 ± 4.29 U/L as well as AST from 180.20 ± 9.47 U/L to 105.10 ± 8.16 U/L. In mercury chloride (HgCl!)-induced damage, glutathione (GSH) increased from 5.1 ± 0.2 to 5.9 ± 0.2 mg/mg protein, SOD elevated from 105 ± 12.1 to 126.3 ± 7.2 U/mg, whereas CAT increased from 72.3 ± 9.1 to 88.1 ± 5.2. MDA also got a lower concentration from 4.8 ± 0.3 to 3.9 ± 0.2 nmol/mg. In the Aflatoxin B1 (AFB1) model, GSH-Px levels increased from 26.16 ± 2.05 to 49.88 ± 2.72 U/mg, and MDA dropped from 0.40 ± 0.02 to 0.17 ± 0.01, which confirmed the curcumin's antioxidant and hepatoprotective roles.

Thymoquinone (TQ) also showcased a strong dose-dependent effect on enzymes like ALT, AST, and oxidative markers. In the paracetamol-induced model, TQ (0.5 mg/kg i.p.) lowered ALT from 245.21 ± 5.63 to 59.63 ± 4.04 U/L, and AST from 339.73 ± 15.67 to 109.83 ± 12.03 U/L. In the acrylamide model, TQ (20 mg/kg) minimized ALT from 52.75 ± 1.08 to 27.20 ± 0.60 and AST from 117.24 ± 4.13 to 65.37 ± 0.90 U/L. Similarly, oxidative markers like GSH increased from 12.30 ± 0.60 to 16.72 ± 0.56, and in contrast, MDA declined from 0.78 ± 0.04 to 0.36 ± 0.01. In diazinon-induced injury, TQ at 10 mg/kg elevated SOD from 18.70 ± 6.20 to 25.00 ± 6.20 U/mL tissue, GSH from 10.90 ± 0.80 to 15.90 ± 1.00, and decreased the MDA from 6.85 ± 1.0 to 4.3 ± 0.3. These findings confirmed the thymoquinone's antioxidant and enzyme-normalizing abilities across various hepatotoxic models.

Stability of pooled dose estimates in both forest plots was assessed by a leave-one-out sensitivity analysis. In the case of curcumin, the pooled mean dose was 194.56 mg/kg, and the 95% CI was 16.31 to 372.81. A deletion of the studies one by one yielded the pooled means of 171.4 to 211.8 mg/kg, showing that none of the studies had any significant impact. The heterogeneity (I2 = 99.9 %) was high all along, which indicated the consistency in variability across models and doses. The total pooled mean dose in thymoquinone forest plot was 27.99 mg/kg (95% CI: -7.6 to 63.59). Exclusion of the study with the highest dose (100 mg/kg) reduced the mean dose to 18.6 mg/kg, whereas elimination of the lowest dose (0.5 mg/kg) resulted in an increase in the mean dose to 33.2 mg/kg. Nonetheless, the level of heterogeneity was substantial (I2 = 99.8%), ensuring that no single study disproportionately influenced the pooled estimate. Therefore, the analysis confirmed the strength and reliability of the cumulative data on dosses of the two compounds.

Table 3 contains animal studies that seem to have a low risk of bias and do well in the areas of selecting patients, balancing groups, and observing the outcomes. The 11 included experimental studies looked at the liver-protective effects of curcumin and thymoquinone using animals that had liver injury caused by chemical agents. Many studies had the same dosages and ways to measure the main results, including looking at liver enzymes and oxidative stress. Following the GRADE approach, the overall evidence was seen as moderate because of differences in study designs, how long treatments lasted, and the outcomes measured.

Risk of Bias

Table 3: Risk of Bias Assessment of In Vitro and In Vivo Studies

Author (Year)	Detection Bias Exposure	Selection Bias	Other Sources of Bias	Detection Bias – Outcome	Selective Reporting Bias	Confounding Bias	Attrition/Exclusion Bias
Li et al., 2021	++	+	+	++	+	+	++
Yang et al., 2024	++	+	+	++	+	+	++
Al-Dossari et al., 2020	++	+	+	++	+	+	++
Zhang et al., 2024	++	+	+	++	+	+	++
Yang et al., 2024	++	+	+	++	+	+	++
Sunoqrot et al., 2024	++	+	+	++	+	+	++
Abduh et al., 2023	++	+	+	++	+	+	++
Abdel-Daim et al., 2020	++	+	+	++	+	+	++
Wang et al., 2023	++	+	+	++	+	+	++
Danaei et al., 2022	++	+	+	++	+	+	++
Behairy et al., 2024	++	+	+	++	+	+	+

++ Definitely low risk, + Probably low risk, - Probably high risk, -- Definitely high risk

DISCUSSION

From the in vivo studies reviewed, curcumin and thymoquinone were found to protect the liver when seen in experimental models of liver injury [24,25]. According to the results, both compounds sharply lower liver enzyme levels (ALT, AST, and ALP) and improve aspects of liver tissue damage, including necrosis, inflammation, and cell degeneration [26].

Curcumin lowers liver enzymes (ALT, AST, ALP) by reducing oxidative stress and inflammation. It scavenges ROS, enhances antioxidant enzymes, and stabilizes liver cell membranes [27]. Curcumin also inhibits pro-inflammatory cytokines like TNF-a (Tumor Necrosis Factor-alpha), helping prevent liver damage and enzyme leakage [28]. Antioxidant and anti-inflammatory activity by curcumin was seen in numerous animal models of liver injury. Antioxidant and anti-inflammatory activity by curcumin were seen in numerous animal models of liver injury [29]. It boosted the levels of antioxidant enzymes like superoxide dismutase and glutathione peroxidase and lessened markers of lipid peroxidation by reducing malondialdehyde [30]. Also, curcumin was found to prevent inflammation by altering the levels of TNF-a, IL-1β, and IL-6 (inflammatory markers) [31]. In many studies, the pathway involving Nrf2/HO-1 was activated, and NF-κB was often found to be inhibited. Several studies pointed out that it may lead to a drop in hepatic stellate cell activation and expression of genes related to fibrosis, which suggests it has antifibrotic qualities [32,33].

Thymoquinone reduces elevated liver enzymes by boosting antioxidant defenses and suppressing inflammation. It increases GSH, SOD, and CAT levels, protecting liver cells from reactive oxygen species (ROS) [34]. It also inhibits NF-κB and TNF-a, preserving hepatocyte function and preventing enzyme release[35]. Thymoquinone also showed that it protects the liver by increasing redox balance,
decreasing the number of inflammatory cytokines, and managing apoptotic signaling [36,37]. It adjusted the balance between Bax and Bcl-2 and lessened caspase-related events in the liver after injury [38]. It was also observed in studies that it stopped hepatic models from making inducible nitric oxide synthase and cyclooxygenase enzymes, showing that it controls inflammation [39].

Although research results are consistent and likely true, the certainty of evidence is lowered by how well the studies were completed. A lot of these studies did not use randomization, hide the allocation of patients, or keep the outcome assessors blinded. Also, differences among studies in animals chosen, methods to induce liver injury, treatment schedules, drug doses, and results reported complicate efforts to compare and combine data [40]. Because the number of included studies was small and mainly the positive studies were included, publication bias cannot be ruled out.

Moreover, having different outcome measures and varying types of comparators makes it less possible

to generalize findings. None of the studies reported data on how these drugs might affect patients over time or how their bodies process them, which is needed for use in clinical settings.

Based on the evidence, curcumin and thymoquinone seem to protect the liver in preclinical settings. At present, the research of chemists and biologists is too limited, and more accurate experimental studies have to be completed to achieve safe and effective ways of using these drugs in humans.

CONCLUSION

Curcumin and thymoquinone are found to have significant properties in preventing liver damage by decreasing oxidative stress, lowering liver enzyme levels, and regulating numerous inflammatory and apoptotic processes. Both substances had consistent protection against liver damage in several tests, suggesting they may be useful for liver disorders.

Even though results show promise, differences in how studies are done and issues translating them into clinical use point to the requirement for more well-conducted studies. It is important for future studies to define appropriate dosage amounts, check the safety of these compounds in the long run, and find the most effective delivery methods to apply curcumin and thymoquinone in the treatment of liver damage.

LIST OF ABBREVIATIONS

ALT: Alanine Aminotransferase
AST: Aspartate Aminotransferase
ALP: Alkaline Phosphatase
TNF-α: Tumor Necrosis Factor-alpha
IL-6: Interleukin-6
IL-1β: Interleukin-1 beta
NF-κB: Nuclear Factor kappa-light-chain-enhancer of activated B cells
Nrf2: Nuclear factor erythroid 2–related factor 2
HO-1: Heme Oxygenase-1

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None

CONFLICT OF INTEREST

None

AUTHORS' CONTRIBUTION

All contributed equally as per ICMJE.

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