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Research Article

Hepatocellular and liver enzyme responses to *Tetrapleura tetraptera* and *Jatropha curcas* (polyherbal TJ) exposure in experimental rats

Efosa Bolaji Odigie and **Blessing Emosho Ogeyemhe**

Department of Medical Laboratory Science, School of Basic Medical Sciences, University of Benin, P.M.B. 1154, Benin City, Nigeria.

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Prof. Dr. Christian Celia

Corresponding Author
Prof. Dr. Blessing Emosho Ogeyemhe
E-mail: blessing.atoigwe@uniben.edu,
Tell: +234 806 521 0159

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Polyherbal formulation, hepatotoxicity, liver enzymes, histology, *Tetrapleura tetraptera*, *Jatropha curcas*.

Abstract

Polyherbal formulations are increasingly used in traditional medicine due to their perceived therapeutic synergy; however, their hepatic safety profiles remain inadequately characterized. This study evaluated hepatocellular integrity and liver enzyme responses following exposure to aqueous extracts of *Tetrapleura tetraptera* fruit and *Jatropha curcas* leaves, administered singly and in combination, in rats. Twenty-four adult female Wistar rats were randomly assigned into four groups: control, *T. tetraptera* (200 mg/kg), *J. curcas* (400 mg/kg), and a combined extract group receiving *T. tetraptera* fruit extract (200 mg/kg) and *J. curcas* leaf extract (400 mg/kg) in a fixed ratio of 1:2 (*T. tetraptera*: *J. curcas*). The treatments were administered orally for 28 consecutive days. Body weight, absolute and relative liver weights were recorded, while serum alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase activities were quantified. Liver tissues were examined histologically using hematoxylin and eosin staining. No significant differences were observed in body weight gain, liver weight indices, or serum liver enzyme activities among the treated groups compared to the control group. Histological evaluation revealed preserved hepatic architecture across all groups, characterized by intact hepatocytes with eosinophilic cytoplasm, centrally placed normochromic nuclei, and well-defined sinusoidal spaces, with no evidence of necrosis, inflammation, or structural distortion. The combined extract group also demonstrated intact portal and lobular organization. The findings indicate that aqueous extracts of *T. tetraptera* fruit and *J. curcas* leaves, administered individually or in combination at the tested doses, did not induce hepatotoxic effects. These results support the hepatic tolerance and short-term safety of the *T. tetraptera* fruit and *J. curcas* leaf polyherbal TJ formulation under controlled experimental conditions.

1. Introduction

Hepatocytes are the primary functional units of the liver and serve as a central cellular interface for metabolic regulation and defense against chemical and inflammatory stress [1]. These cells coordinate xenobiotic metabolism, protein synthesis, and lipid homeostasis while maintaining an intracellular redox balance through tightly regulated enzymatic pathways [2]. Hepatocytes are particularly vulnerable to oxidative injury and enzymatic disruption following exposure to bioactive compounds owing to their central role in biotransformation and molecular signaling [1, 2]. Consequently, alterations in hepatocellular architecture and enzyme activity are widely recognized as early indicators of hepatic dysfunction in experimental toxicology and pharmacology studies [3].

Herbal medicine continues to play a central role in healthcare delivery, particularly in low- and middle-income countries, where plant-based therapies are frequently used for the management of chronic and metabolic diseases [4, 5]. In recent years, scientific interest has increasingly focused on polyherbal formulations due to their potential for synergistic biological activity and reduced toxicity, compared to the single plant extracts [6]. This growing attention is supported by extensive evidence of the therapeutic relevance of medicinal plants and their bioactive constituents in human health and disease management [4]. Despite this interest, the hepatic safety profile and biochemical consequences of combined herbal exposure remain inadequately characterized, particularly at the hepatocellular and enzymatic levels [7].

Tetrapleura tetraptera is a medicinal plant widely distributed in West Africa and is commonly used as both a culinary spice and therapeutic agent. Phytochemical investigations have identified flavonoids, tannins, saponins, and phenolic compounds as the major constituents of the fruit [8, 9]. These bioactive compounds possess antioxidant and anti-inflammatory properties associated with hepatocellular membrane stabilization and modulation of liver enzyme activity in experimental models [10, 11]. Recent studies have demonstrated that *T. tetraptera* fruit extract can attenuate oxidative stress and preserve hepatic architecture following chemically induced liver injury [9].

Jatropha curcas is a multipurpose plant traditionally employed in the treatment of inflammatory conditions, infections, and liver related disorders. The leaves contain flavonoids, diterpenes, and phenolic acids that exhibit notable antioxidant and anti-inflammatory activities [12, 13]. Experimental studies involving Jatropha species have reported the normalization of hepatic enzyme levels following the controlled administration of leaf extracts, suggesting potential hepatoprotective effects [14]. However, the presence of toxic constituents in certain parts of the plant necessitates careful dose- dependent evaluation, particularly when *J. curcas* is used in combination with other medicinal plants [15, 16].

Polyherbal TJ, a combination of *Tetrapleura tetraptera* fruit and *Jatropha curcas* leaf extracts in a fixed ratio of 1:2 was designed to leverage the complementary antioxidant and anti-inflammatory phytochemicals of both plants. This formulation provides a rational basis for assessing hepatic tolerance, given the reported hepatoprotective effects of each extract used individually and in combination.

The evaluation of hepatic responses to polyherbal exposure requires an integrated biochemical and histological approach. Serum enzymes, such as alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase, serve as reliable biomarkers of hepatocellular injury and biliary dysfunction [17, 18]. Histopathological examination complements biochemical findings by directly visualizing hepatocyte integrity, sinusoidal organization, and pathological features such as steatosis or cellular degeneration [19]. Experimental rat models are widely accepted for assessing hepatic responses to herbal formulations due to their physiological similarity to humans and reproducibility under controlled laboratory conditions [20]. Therefore, investigation of hepatocellular and enzymatic responses following polyherbal exposure provides essential insights into hepatic tolerance, safety, and potential protective interactions. This study examined hepatocellular integrity and liver enzyme responses following polyherbal exposure in experimental rats, providing evidence-based insights into the hepatic safety and tolerance of combined herbal formulations.

2. Materials and methods

2.1. Plant material

Fresh fruits of *T. tetraptera* and *J. curcas* leaves were collected from a natural habitat in southwestern Nigeria. The plant materials were identified and authenticated by a qualified taxonomist. Voucher specimens were deposited in a recognized herbarium under voucher numbers UBH-T472 (*T. tetraptera*) and UBH-J404 (*J. curcas*) for future reference. All procedures involving plant collection and use were conducted in accordance with the applicable research and ethical guidelines.

2.2. Preparation and extraction of plant materials

The collected plant materials were thoroughly washed with clean water to remove adhering debris and air dried at room temperature to prevent degradation of heat sensitive constituents. The dried fruits of *T. tetraptera* and leaves of *J. curcas* were

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separately pulverized into fine powders using a mechanical grinder. Aqueous extraction was performed using a modified cold maceration method. Briefly, 500 g of each powdered plant material was soaked separately in 1.5 L of distilled water and allowed to stand for 24 h with intermittent stirring to enhance the extraction efficiency. The mixtures were homogenized using an electric blender and kept overnight at 4 °C. The suspensions were filtered through a muslin cloth to remove plant residues. The filtrates were concentrated under reduced pressure at 40 °C using a rotary evaporator and subsequently freeze dried to obtain powdered aqueous extracts. The extracts were stored in airtight containers at 4 °C until use.

2.3. Acute toxicity study (LD_{50})

Information on the acute toxicity and median lethal dose (LD_{50}) of *T. tetraptera* fruit and *J. curcas* leaf extracts was obtained from previously published toxicological studies [8-10, 21]. Published reports indicate that aqueous fruit extracts of *T. tetraptera* do not cause mortality or overt signs of toxicity in rodents following oral administration at doses up to 5000 mg/kg body weight [8, 9]. Additional reviews of the biological and toxicological properties of *T. tetraptera* have further described a broad safety margin at moderate experimental doses [10]. For *J. curcas*, available toxicological evaluations report that aqueous leaf extracts, when appropriately processed and administered within defined dose limits, were tolerated in experimental animals without significant adverse effects [7, 21]. Based on these documented findings, the doses used in our study were within the reported non-toxic ranges and were considered suitable for subacute exposure.

2.4. Experimental animals

Twenty-four apparently healthy adult female Wistar rats weighing between 107 g and 155 g were used in this study. The animals were obtained from a registered laboratory animal facility and housed in well-ventilated wire mesh cages under standard laboratory conditions. Environmental conditions were maintained at a temperature of 22-25 °C with a 12 h light/12 h dark cycle. Clean wood shavings were used as bedding and were changed regularly. Rats were allowed a two-week acclimatization period prior to the commencement of the experiment and had free access to standard laboratory feed and clean drinking water *ad libitum*. Animals were observed daily for general health status, behavior, and signs of distress, throughout the experimental period. All experimental procedures were conducted in accordance with internationally accepted guidelines for the care and use of laboratory animals and were approved by the accredited Ethics Review Committee.

2.5. Experimental design

The animals were randomly allocated to four experimental groups of six rats each to minimize selection bias (n=6). Group A served as the control and received standard feed and distilled water only. Group B received *T. tetraptera* fruit extract at a dose of 200 mg/kg body weight. Group C received *J. curcas* leaf extract at a dose of 400 mg/kg body weight. Group D received polyherbal formulated extract (Polyherbal TJ), comprising of *T. tetraptera* fruit (200 mg/kg) and *J. curcas* leaf extract (400 mg/kg) in a fixed ratio of 1:2 (*T. tetraptera*: *J. curcas*). All treatments were administered orally once daily for 28 consecutive days using an oral gavage. The volume of administration did not exceed 1 mL per 100 g body weight.

2.6. Tissue collection and processing

At the end of the treatment period, the animals were humanely sacrificed by cervical dislocation. The abdominal cavity was opened through a midline incision, and the liver was carefully excised, rinsed with normal saline, and fixed in 10% neutral buffered formalin. Fixed liver tissues were processed using routine histological techniques. Dehydration was carried out in ascending grades of alcohol, followed by clearing in xylene and embedding in paraffin wax. Tissue sections (5 µm thick) were cut using a rotary microtome and mounted on glass slides. The sections were then deparaffinized and stained with hematoxylin and eosin. Histological examination was performed using a light microscope, and photomicrographs were captured for histomorphological evaluations. Histopathological assessment was conducted without prior knowledge of the treatment allocation to minimize observer bias.

2.7. Blood sample collection and biochemical analysis

Blood samples were collected by cardiac puncture immediately after sacrifice and allowed to clot at room temperature. Serum was separated by centrifugation at 3000 rpm for 10 minutes and used for biochemical analysis of liver enzyme activities. Serum alanine aminotransferase (ALT) activity was determined

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using the Alanine Transaminase Activity Assay Kit (Colorimetric), ab105134 (Abcam, United Kingdom), following the manufacturer's instructions. In this assay, ALT catalyzes the conversion of alanine and α-ketoglutarate to pyruvate and glutamate, respectively. The amount of pyruvate formed was coupled to a colorimetric reaction, and the absorbance was measured at 570 nm using a microplate reader.

Serum aspartate aminotransferase (AST) activity was measured using the Aspartate Aminotransferase Activity Assay Kit, ab105135 (Abcam, United Kingdom), which quantifies AST-catalyzed reactions via a chromogenic end product detectable at 450 nm on a microplate reader. Alkaline phosphatase (ALP) activity was assessed using the Alkaline Phosphatase Assay Kit, MAK447 (Sigma-Aldrich, United States). This assay utilizes p-nitrophenyl phosphate as a substrate, which is hydrolyzed by ALP to produce a yellow chromogen. The optical density of the product was measured at 405 nm.

All absorbance measurements were performed using a Thermo Scientific™ Multiskan™ FC Microplate Photometer (Thermo Fisher Scientific, United States). The instrument was calibrated according to the manufacturer's protocol before analysis. Enzyme activity was calculated based on standard curves and expressed in international units per liter (IU/L).

2.8. Statistical analysis

Data obtained from biochemical analyses were expressed as mean ± standard error of the mean (SEM). Statistical analyses were performed using appropriate statistical software. Differences among groups were analyzed using one-way analysis of variance, followed by suitable post hoc tests. Statistical significance was set at $p < 0.05$.

3. Results and discussion

The effects of polyherbal exposure on body weight, liver weight, serum liver enzyme activities, and hepatic histology are presented in Table 1, Table 2, and Fig 1. As shown in Table 1, no statistically significant differences were observed in the initial body weight, final body weight, absolute liver weight, or relative liver weight among the treated groups compared to the control group ($p > 0.05$). Although slight numerical increases in liver weight and relative liver weight were recorded in rats administered the plant extracts, either singly or in combination, these variations remained within physiological limits and did not indicate hepatomegaly or adverse organ enlargement. Body weight gain across all groups further indicated that the administered doses of the extracts did not impair the growth or general health status of the animals during the experimental period.

Organ weight assessment is a sensitive indicator of systemic and organ-specific toxicity, particularly for the liver, which serves as the primary site for xenobiotic metabolism. The absence of significant alterations in liver weight observed in the present study suggests that the aqueous extracts of *T. tetraptera* fruit and *J. curcas* leaves at the selected doses were well tolerated. Similar observations have been reported in experimental studies evaluating the hepatic safety of medicinal plants and polyherbal formulations at moderate doses [17, 20].

The serum liver enzyme activities are presented in Table 2. The activities of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP) did not differ significantly among the treated groups compared to the control group ($p > 0.05$). ALT and AST are cytosolic enzymes released into circulation following hepatocellular membrane damage, whereas, ALP is commonly associated with biliary tract integrity and membrane transport processes. The maintenance of these enzyme activities within the normal physiological range indicates preserved hepatocellular integrity and the absence of enzyme leakage, suggesting that the administered extracts did not induce biochemical hepatotoxicity.

The biochemical findings of this study are consistent with previous reports indicating that *T. tetraptera* possesses hepatoprotective properties, attributed largely to its flavonoid and phenolic constituents [8-11]. In the present study, serum ALT, AST, and ALP activities in rats administered *T. tetraptera*, *J. curcas*, or their combination did not differ significantly from those in the control group (Table 2), indicating preserved hepatocellular integrity. Although the antioxidant activities of these plants have been reported in previous studies [10-13], antioxidant parameters were not directly assessed in the present study. Similarly, reports of normalization of liver enzyme activities following *J. curcas* administration were derived from experimental models involving chemically induced hepatic injury [12-14]. In contrast, no hepatotoxic challenge was applied in the present

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Table 1. Effect of *T. tetraptera* fruit and *J. curcas* leaf exposure on body weight and liver weight of experimental rats.

Group	Treatment	Initial Body Weight (g)	Final Body Weight (g)	Liver Weight (g)	Relative Liver Weight (%)
A	Control (Distilled water)	127.50 ± 3.77	153.50 ± 6.66	7.15 ± 0.72	4.66
B	*T. tetraptera* fruit extract (200 mg/kg)	115.00 ± 2.97	132.75 ± 2.46	8.28 ± 0.56	6.24
C	*J. curcas* leaf extract (400 mg/kg)	139.25 ± 8.38	152.25 ± 7.78	8.45 ± 0.42	5.55
D	*T. tetraptera* (200 mg/kg) + *J. curcas* (400 mg/kg)	143.00 ± 4.64	158.50 ± 7.96	8.95 ± 0.93	5.65

Values are presented as mean ± SEM (n = 6). Relative liver weight (%) was calculated as (liver weight/final body weight) × 100. One-way ANOVA followed by Tukey's post hoc test was used for multiple comparisons. No statistically significant differences were observed among groups compared with the control ($p > 0.05$).

Table 2. Effect of *T. tetraptera* fruit and *J. curcas* exposure on serum liver enzyme activities in experimental rats.

Group	Treatment	ALT (U/L)	AST (U/L)	ALP (U/L)
A	Control (Distilled water)	6.00 ± 0.41	8.25 ± 0.63	9.50 ± 0.65
B	T. tetraptera fruit extract (200 mg/kg)	6.00 ± 0.00	7.00 ± 1.00	10.50 ± 0.50
C	J. curcas leaf extract (400 mg/kg)	6.75 ± 0.25	8.00 ± 0.41	11.75 ± 0.48
D	T. tetraptera (200 mg/kg) + J. curcas (400 mg/kg)	5.75 ± 0.25	7.25 ± 0.25	10.25 ± 1.11

Values are presented as mean ± SEM (n = 6). One-way ANOVA followed by Tukey's post hoc test was used for multiple comparisons. No statistically significant differences were observed among groups compared with the control ($p > 0.05$).

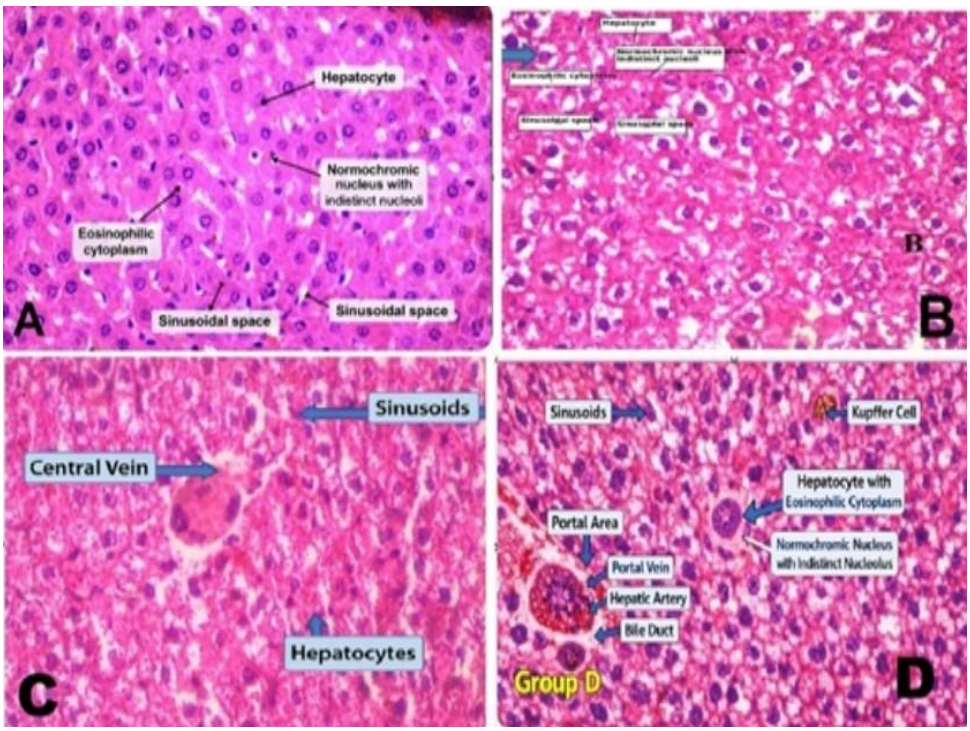

Figure 1. Representative liver histology showing preserved hepatic architecture across groups (H&E, ×400).

study. The absence of enzyme elevation in the combined extract group (Table 2) indicates that the polyherbal TJ formulation did not elicit hepatotoxic or synergistic adverse effects at the tested doses.

The histological evaluation of liver sections is shown in. Fig 1 microscopic examination revealed a preserved hepatic architecture across all groups. Hepatocytes appeared polygonal and were arranged

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in cords, displaying eosinophilic cytoplasm with centrally placed, normochromic nuclei and indistinct nucleoli. The sinusoidal spaces were intact and well defined, with no evidence of hepatocellular degeneration, necrosis, steatosis, or inflammatory infiltration. In rats administered the combined extracts (Fig 1D), additional hepatic structures, including the central vein, portal vein, hepatic artery, bile duct, and Kupffer cells, were clearly identifiable, further indicating the preservation of normal lobular organization.

The histological findings corroborated the biochemical data and reinforced the conclusion that the administered plant extracts did not compromise hepatic structure or function. The preservation of liver histoarchitecture following herbal exposure has been widely associated with the antioxidant and anti-inflammatory actions of phytochemicals such as flavonoids, saponins, and phenolic acids, which mitigate oxidative stress and stabilize cellular membranes [1, 2, 4, 10]. These compounds play critical roles in maintaining hepatocellular homeostasis and preventing oxidative injury during xenobiotic metabolism [1, 3].

Fig. 1 show preserved hepatic architecture across all groups, with hepatocytes exhibiting eosinophilic cytoplasm and centrally placed normochromic nuclei with indistinct nucleoli. Sinusoidal spaces were intact, and no evidence of hepatocellular degeneration, inflammatory infiltration, or structural distortion was observed following the administration of plant extracts, either singly or in combination.

Taken together, the concordance between body and organ weight indices, serum liver enzyme activities, and histological findings provides strong evidence that the aqueous extracts of *T. tetraptera* fruit and *J. curcas* leaves, administered singly or in combination, did not exert hepatotoxic effects under the experimental conditions employed. This observation supports previous reports on the hepatic safety of medicinal plants when used within controlled dose ranges [17-19]. However, herb-induced liver injury has been documented in cases of prolonged exposure, inappropriate dosing, or the use of poorly characterized herbal preparations [15, 19]. Therefore, while the present findings suggest hepatic tolerance and safety following short-term exposure, further studies involving longer durations, higher doses, and molecular markers of oxidative stress and inflammation are required to fully elucidate the long-term hepatic effects of these polyherbal formulations [3, 15, 21].

3.1. Limitations of the study

This study was limited to a 28-day exposure period and focused on routine biochemical and histological assessments, which may not fully reflect the long-term or molecular hepatic effects. The use of only female rats and a single dose range further limits broader biological extrapolation.

4. Conclusions

This study showed that aqueous extracts of *T. tetraptera* fruit and *J. curcas* leaves, administered singly or mixed, did not adversely affect liver weight, serum liver enzyme activities, or hepatic histoarchitecture in experimental rats. These findings indicate preserved hepatocellular integrity and enzymatic function, suggesting hepatic tolerance to the polyherbal formulation at the tested doses. Further studies involving longer exposure periods and additional mechanistic endpoints are recommended to establish long-term hepatic safety.

Ethical statement

All experimental procedures were performed in accordance with internationally recognized ethical standards for animal research and were approved by the accredited Institutional Ethics Review Committee (approval number: MAFSAEC: 025-08/25/0043).

Disclaimer (artificial intelligence)

The authors acknowledge the use of ChatGPT (OpenAI) exclusively for language refinement, formatting, and alignment with the journal's author guidelines. Artificial intelligence tools were not utilized for data generation, statistical analysis, interpretation of results, or scientific decision-making. The authors retain full responsibility for the integrity and content of the manuscript.

Authors' contributions

Conceptualization, B.E.O. and E.B.O.; Methodology, B.E.O.; Software, B.E.O.; Validation, B.E.O. and E.B.O.;

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Formal Analysis, B.E.O.; Investigation, B.E.O.; Resources, E.B.O.; Data Curation, B.E.O.; Writing - Original Draft Preparation, B.E.O.; Writing Review & Editing, B.E.O. and E.B.O.; Visualization, B.E.O.; Supervision, E.B.O.; Project Administration, E.B.O.; Funding Acquisition, Not applicable.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

Authors declare that there is no conflict of interest.

References

1. Gong, J.; Tu, W.; Liu, J.; Tian, D. Hepatocytes: A key role in liver inflammation. Front. Immunol. 2023, 13, 1083780. https://doi.org/10.3389/fimmu.2022.1083780
2. Ma, X.; Huang, T.; Chen, X.; Li, Q.; Liao, M.; Fu, L.; Huang, J.; Yuan, K.; Wang, Z.; Zeng, Y. Molecular mechanisms in liver repair and regeneration: from physiology to therapeutics. Signal Transduct Target Ther. 2025, 10, 63. https://doi.org/10.1038/s41392-024-02104-8
3. Kim, Y.; Kim, H.; Kim, Y. Advancing hepatotoxicity assessment: current advances and future directions. Toxicol Res. 2025, 41, 303–323. https://doi.org/10.1007/s43188-025-00289-w
4. Latif, R.; Nawaz, T. Medicinal plants and human health: a comprehensive review of bioactive compounds, therapeutic effects, and applications. Phytochem Rev. 2025. https://doi.org/10.1007/s11101-025-10194-7
5. Asafo-Agyei, T.; Appau, Y.; Bobi, B.K.; Asase, A. Medicinal plants used for management of diabetes and hypertension in Ghana. Heliyon. 2023, 9(12), e22977. https://doi.org/10.1016/j.heliyon.2023.e22977
6. Patel, V.R.; Saini, S.; Dwivedi, J.; Gupta, A.K.; Shrivastava, A.K.; Misra, A. Exploring the concept and scope of polyherbal formulations: a comprehensive review. Int. J. Herbal Med. 2025, 13(2), 09-16. https://doi.org/10.22271/flora.2025.v13.i2a.973
7. Ezrari, S.; Ben Khadda, Z.; Boutagayout, A.; Rehali, M.; Jaadan, H.; El Housni, Z.; Khoulati, A.; Saddari, A.; Maleb, A. Health risks and toxicity mechanisms of medicinal and aromatic plants: a comprehensive review. Fitoterapia. 2025, 184, 106630. https://doi.org/10.1016/j.fitote.2025.106630
8. Bonsou, I.N.; Mbaveng, A.T.; Nguenang, G.S.; Chi, G.F.; Kuete, V.; Efferth, T. Cytotoxicity, acute and sub-chronic toxicities of the fruit extract of *Tetrapleura tetraptera*. BMC Complement Med. Ther. 2022, 22, 178. https://doi.org/10.1186/s12906-022-03659-1
9. Ekeanyanwu, C.R.; Nkwocha, C.C.; Ekeanyanwu, C.L. Phytochemical diversity and safety profile of hot water extract from *Tetrapleura tetraptera* fruit. BMC Complement Med Ther. 2024, 24, 374. https://doi.org/10.1186/s12906-024-04681-1
10. Mensah, R.Q.; Adusei, S.; Azupio, S.; Kwakye, R. Nutritive value, biological properties, health benefits and applications of *Tetrapleura tetraptera*: an updated review. Heliyon. 2024, 10(6), e27834. https://doi.org/10.1016/j.heliyon.2024.e27834
11. Kusi, S.; Larbie, C.; Sarfo-Antwi, F. Hepatoprotective effects of *Tetrapleura tetraptera* stem bark extracts in drug-induced toxicities in rats. Curr. Res. Complement. Altern. Med. 2023, 7, 201. https://doi.org/10.29011/2577-2201.100201
12. Kamaruddin, A.; Harun, W.H.A.W.; Bakri, M.M.; Abidin, S.A.Z.; Giribabu, N.; Syed Abdul Rahman, S.N. Phytochemical profile and antimicrobial activity of *Jatropha curcas* extracts against oral microorganisms. Heliyon, 2024, 10(17), e33422. https://doi.org/10.1016/j.heliyon.2024.e33422
13. Adeyemo, A.G.; Awote, O.K.; Bello, O.P.; Sanusi, R.B.; Akinyemi, M.O.; Eshinlokun, I.A.; Mabodu, M.T.; Olarenwaju, H.O.; Amodu, A.N. Phytochemical screening, in vitro antioxidant and anti-inflammatory activity of aqueous extract of *Jatropha curcas*. South Asian Res. J. Nat. Prod. 2023, 6(3), 239-247. https://journalsarjnp.com/index.php/SARJNP/article/view/129.
14. Iqbal, M.O.; Naeem, M.; Mumtaz, A.; Ahmed, M.M.; Ahmad, A.; Riaz, R.; Mesbah, Z.; Munawar, N. Biochemical evaluation and medicinal ability of *Jatropha mollissima* in hepatic disorders. Am. J. Transl Res. 2022, 14(10), 7178–7188.
15. Łupina, K.; Nowak, A.; Jabłońska, A.; Potaczek, A.; Salacha, J.; Ilkiewicz, Ł.; Kalisz, A.; Janczura, J. Herb-induced liver injury. Livers. 2025, 5(4), 55. https://doi.org/10.3390/livers5040055
16. Mykhailenko, O.; Jalil, B.; McGaw, L.J.; Echeverría, J.; Takubessi, M.; Heinrich, M. Climate change and the sustainable use of medicinal plants: a call for "new" research strategies. Front. Pharmacol. 2025, 15, 1496792. https://doi.org/10.3389/fphar.2024.1496792

17. Begum, R.; Papia, S.A.; Begum, M.M.; Wang, H.; Karim, R.; Sultana, R.; Das, P.R.; Begum, T.; Islam, M.R.; Manwar, N.; Rahman, M.S. Evaluation of hepatoprotective potential of polyherbal preparations in CCl_4-induced hepatotoxicity in mice. Adv. Pharmacol Pharm. Sci. 2022, 2022, 3169500. https://doi.org/10.1155/2022/3169500
18. Ammari, A.A.; Alhimaidi, A.R.; Amran, R.A.; Rady, A.; Aljawdah, H.; Al-Mekhlafi, F. Evaluating the hepatoprotective effects of polyherbal extracts in rats. Arq. Bras. Med. Vet. Zootec. 2025, 77(4), e13390. http://dx.doi.org/10.1590/1678-4162-13390
19. Aladejana, E.B.; Aladejana, A.E. Hepatoprotective activities of polyherbal formulations: a systematic review. J. Med. Plants Econ. Dev. 2023, 7(1), a206. https://doi.org/10.4102/jomped.v7i1.206
20. Ang, C.H.; Arandjelovic, P.; Cheng, J.; Yang, J.; Guo, F.; Yu, Y.; Nelameham, S.; Whitehead, L.; Li, J.; Silver, D.L.; Barker, N.; Visvader, J.E.; Chow, P.K.H.; Smyth, G.K.; Chen, Y.; Virshup, D.M.; Fu, N.Y. Self-maintenance of zonal hepatocytes during adult homeostasis and their complex plasticity upon distinct liver injuries. Cell Rep. 2025, 44(11), 115093. https://doi.org/10.1016/j.celrep.2025.115093
21. Jităreanu, A. Current trends in toxicity assessment of herbal medicines: A narrative review. Processes, 2023, 11(1), 83. https://doi.org/10.3390/pr11010083