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RETRACTED: A Polyphenol-Rich Fraction from *Eugenia uniflora* Exhibits Antioxidant and Hepatoprotective Activities In Vivo

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Abstract: Leaves from *Eugenia uniflora*, the red Brazilian cherry, have a high content of flavonoids that possess several biological effects such as anti-inflammatory, antioxidant, and antidiabetic activities. However, their influence on carbon tetrachloride (CCl_4)-induced acute liver injury in rats has not been investigated. In the current study, a bioguided fractionation assay revealed that the ethyl acetate fraction (EAF) of *Eugenia uniflora* is the safest and most active fraction. LC-MS analysis of the ethyl acetate fraction revealed 22 secondary metabolites, mainly myricetin and quercetin derivatives. EAF did not show toxicity up to 2000 mg/kg, and exhibited antioxidant activities in vitro in DPPH assay with IC_{50} of 3.35 µg/mL. Additionally, EAF exhibited substantial antioxidant activities in vivo by counteracting the oxidative damage of the prooxidant juglone [80 µM] in *Caenorhabditis elegans* model organism and increased its survival rate in a dose-dependent fashion through the DAF-16/Foxo pathway. Furthermore, the hepatoprotective activity of EAF (200 mg/kg against carbon tetrachloride (CCl_4) intoxicated male Wistar rats was assessed. EAF significantly inhibited CCl_4-induced elevation of alanine aminotransferase (ALT), aspartate transaminase (AST), total bilirubin (TB), total cholesterol (TC), and triglycerides (TG), in the blood serum and prevented lipid peroxidation and restored superoxide dismutase (SOD) activity and glutathione (GSH) content in liver tissues. The observed hepatoprotective effects of EAF, which were supported by histopathological observations as pretreatment with EAF, effectively attenuated the CCl_4-induced histopathological changes. In conclusion, EAF of *Eugenia uniflora* leaves has substantial hepatoprotective activities against CCl_4 induced acute liver injury in rats due to its antioxidant activity.

Keywords: *Eugenia uniflora*; antioxidant; *Caenorhabditis elegans*; hepatoprotection; LC-MS/MS; polyphenols; myricetin

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1. Introduction

The liver is the main organ responsible for performing diverse pivotal metabolic functions. It plays a major role in carbohydrate, lipid, and protein metabolism. It acts as a storage site for glycogen; vitamins A, D, and B12; and iron. Moreover, it synthesizes 90% of the plasma proteins, and produces the bile [1,2]. In addition, it controls the detoxification of a variety of exogenous substances through oxidation, reduction, hydrolysis, and conjugation to facilitate their elimination from the body [1–3].

Venous blood emerging out of the intestine passes first to the liver through the hepatic portal vein before reaching the systemic circulation [1]. This implies that the hepatocytes are exposed to all toxins and harmful substances taken orally. Therefore, they are highly susceptible to damage. On the other hand, hepatic metabolic reactions can produce many reactive oxygen and nitrogen species. Effective quenching of these species is a crucial process in our body to prevent cellular injury. However, inefficient reduction of these species will lead to a high level of oxidative stress that will increase lipid peroxidation and oxidative damage of proteins and DNA (causing mutations). Oxidative stress is involved in the pathogenesis of inflammation, cell death, neurodegenerative diseases, and cancer [4,5].

Several hepatic defense mechanisms are involved in protection against oxidative damage. These include glutathione reductase, an enzyme that regenerates the reduced form of glutathione, a physiological antioxidant molecule. Another player is superoxide dismutase, which detoxifies the superoxide radical into molecular oxygen and hydrogen peroxide, which is then further detoxified by catalase, which converts it into water and oxygen [5].

Hepatoprotective drugs can improve the ability of the liver to counteract oxidative stress and necrosis and to regenerate after hepatocellular injury. Hepatoprotective agents of a natural origin are important pharmaceutical products and food supplements. These include glycyrrhizin, ellagic acid, phyllanthin, and silymarin [6]. The search for new hepatoprotective substances is an ongoing area of research, since the rate of hepatocellular diseases and related deaths is increasing worldwide.

Eugenia uniflora (Myrtaceae), commonly known as pitanga or red Brazil cherry, is native to the Amazon forest in Brazil and is currently cultivated worldwide [7]. Aqueous infusion of the leaves has been used in folk medicine to treat hypertension and as a diuretic. Moreover, it is traditionally used to treat intestinal troubles fever, rheumatoid arthritis, inflammation, gout, bronchitis, and influenza, and is employed as an astringent and stomachic [7].

Several biological activities have been reported for extracts from this plant. These include anti-inflammatory, antioxidant, analgesic antihypertensive, antibacterial, antifungal, antiviral, anti-trypanosomal, antidiarrheal, and diuretic activities, as well as inhibiting the digestion and absorption of fats and carbohydrates from the intestine [8–15]. Its extract is rich in terpenoids [7], tannins, and flavonoids [8,12–15]. Recently, we isolated 17 secondary metabolites from a bioactive leaf extract that exhibited antioxidant, anti-inflammatory, pain killing, and antidiabetic activities in vivo [15]. To date, information about a potential hepatoprotective effect is lacking.

Acute liver injury induced by CCl_4 is the most intensively studied system to induce oxidative hepatotoxicity [16], because CCl_4 can produce significant hepatotoxicity in rodents (both rats and mice), and acute administration of CCl_4 causes extensive necrosis [17]. In hepatocytes, CCl_4 is metabolized by the cytochrome P450 to produce highly reactive free radicals [18]. Oxidative stress, a physiological status associated with unbalance between free radical and antioxidant defences [15,19–21], plays a crucial role in the pathogenesis of CCl_4-induced hepatic injury. Besides that, ALT and AST serum enzymes have been known to serve as markers for showing the level of hepatotoxicity in rats. In addition, an increase in lipid peroxidation, a decrease in superoxide dismutase (SOD), and the disintegration of the glutathione (GSH) are related to liver damage caused by CCl_4 [22]. Therefore, the aim of this study was to investigate the antioxidant and hepatoprotective potential of a polyphenol rich fraction from *E. uniflora* leaves in vivo models and its antioxidant activities in vitro. Moreover, the phytochemical composition of the fraction was profiled using LC-MS/MS.

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2. Results

2.1. Chemical Composition

The metabolite profile of the EAF was characterized utilizing LC-MS/MS. Twenty-two secondary metabolites were tentatively identified, and they were mainly myricetin and quercetin glucosides (Table 1 and Figure 1). The individual components were identified based on their protonated molecular ions, mass fragmentation, and in comparison with published data and available authentic compounds.

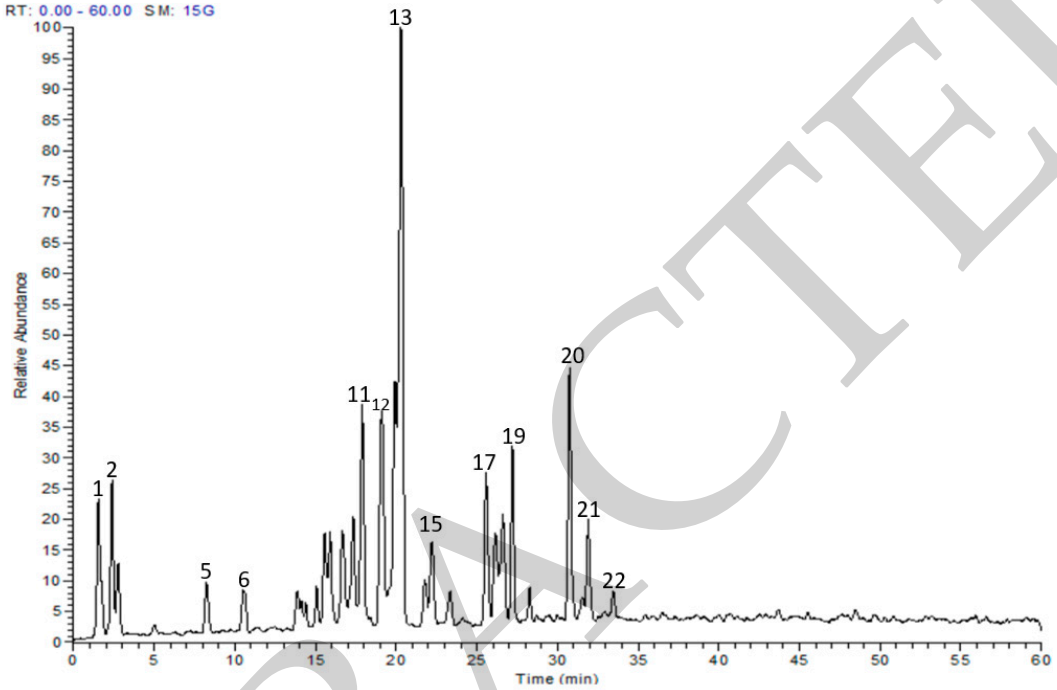


Figure 1. LC-MS profile of the ethyl acetate fraction of *E. uniflora* leaves.

Table 1. Polyphenolics from ethyl acetate fraction (EAF) using LC-MS/MS.

No.	t_R (min)	$[M-H]^-$ (*m/z*)	MS/MS	Proposed Compound	Content (%)
1	1.53	191	111, 127	Quinic acid	4.74
2	2.37	169	125	Gallic acid *	4.07
3	2.89	483	169	Digalloyl-hexoside	2.18
4	5.02	633	301	Galloyl-HHDP-hexoside	0.40
5	8.25	453	169, 285, 313	Pyrogallol-O-methylgalloyl glucose	1.61
6	10.50	337	191	*p*-coumarolylquinic acid	1.80
7	13.83	275	275, 257	3,4,8,9,10-pentahydroxy-6-oxobenzo[c]chromene	2.43
8	15.07	479	151, 317	Myricetin-3-*O*-*β*-D-glucoside *	1.03
9	15.51	479	151, 317	Myricetin-3-*O*-*β*-D-galactoside *	2.86
10	17.13	449	151, 179, 317	Myricetin pentoside	3.75
11	17.90	449	151, 179, 317	Myricetin pentoside	6.74
12	19.07	463	151, 179, 317	Myricetin rhamnoside	7.65
13	20.30	463	151, 179, 317	Myricetin-3-*O*-rhamnoside *	27.89
14	21.71	463	151, 179, 301	Quercetin glucoside	1.60
15	22.23	433	151, 179, 301	Quercetin pentoside	3.21
16	23.36	433	151, 179, 301	Quercetin pentoside	1.55
17	25.59	447	151, 179, 301	Quercetin rhamnoside	4.88
18	26.62	447	151, 179, 301	Quercetin rhamnoside	4.56
19	27.16	431	269	Apigenin glucoside	4.73
20	30.75	615	179, 317, 463	Myricetin galloyl-rhamonside	7.21
21	32.01	431	285	Kaempferol rhamnoside	4.07
22	33.42	521	179, 317, 479	Myricetin-3-*O*-[6′′-*O*-*β*-D-acetyl galactoside] *	1.03

* Previously isolated from the plant [15].

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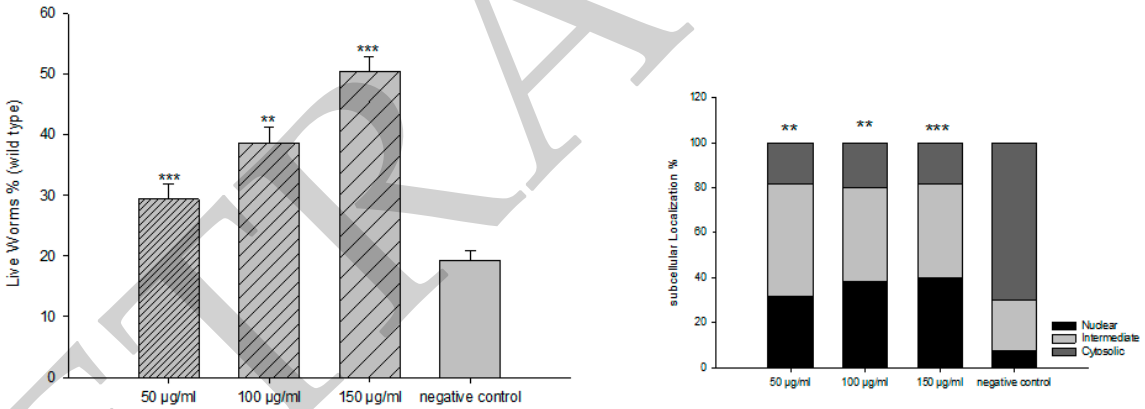
2.2. Antioxidant Activities In Vitro

Initially, the antioxidant activities of different extracts were investigated using DPPH assay. The EAF showed the highest activity among them (Table 2).

Table 2. DPPH activities of different fractions of *E. uniflora* leaves.

Extract or Fraction	DPPH (IC_{50} µg/mL)
N-Hexane	>200
Ethyl acetate	3.35
N-Butanol	8.8
The rest	97.32
Methanol extract	7.45

We then investigated the toxicity of all fractions and the extract in *C. elegans*. All fractions exhibited significant toxicity, except the EAF with a concentration up to 300 µg/mL. From DPPH activity and *C. elegans* toxicity, we used EAF for further experiments. For the survival rate of *C. elegans* under oxidative stress, we explored three different concentrations of EAF (50, 100, and 150 µg/mL) to counteract the toxic effects of the prooxidant juglone [80 µM]. With respect to the control group, EAF increased the survival rate in a dose-dependent manner (Figure 2a). We further investigated whether EAF mediates its antioxidant activity through the DAF-16/FoxO pathway. EAF induced nuclear localization of DAF-16::GFP, indicating that the in vivo antioxidant effect could involve the DAF-16/FOXO signalling pathway (Figure 2b).



(a) (b)

Figure 2. Influence of EAF on the survival rates of worms (N2, wild-type) under juglone treatment (80 µM), mean ± SEM, and $n = 3$ (**a**). DAF-16::GFP translocation by EAF in mutant TJ356 worms (**b**). DAF-16 subcellular localization pattern is illustrated as the percentage cytosolic, intermediate, and nuclear translocation of DAF-16::GFP. *** $p < 0.001$, ** $p < 0.01$, related to control was analyzed by one-way ANOVA.

2.3. Acute Oral Toxicity Study

Oral administration of 2000 mg/kg EAF to three male Wistar rats does not cause any death for 24 h, and there was no change in the behavior of all the rats throughout an observation period of 14 days. The physical activity of all the rats was normal. A prepetition of the experiment with three further animals gave identical results, and no mortality occurred. According to the Acute Toxic Class Method reported in OECD Guidelines No.423, EAF can be classified as category 5 with LD_{50} over 2000 mg/kg.

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2.4. Effect of EAF on Serum Hepatotoxicity Markers

The data in Figure 3 indicate that challenging rats with CCl_4 resulted (as expected) in significant elevations in serum activities of ALT and AST. This was accompanied by significant rise in serum levels of TB, TC, and TG. However, pretreatment of animals with EAF apparently protected them, as seen in the normalization of the toxicity parameters. It is noteworthy to report that the preventive activities of EAF were comparable to those of silymarin and the values of TB, TC and TG did not differ significantly from the control group.

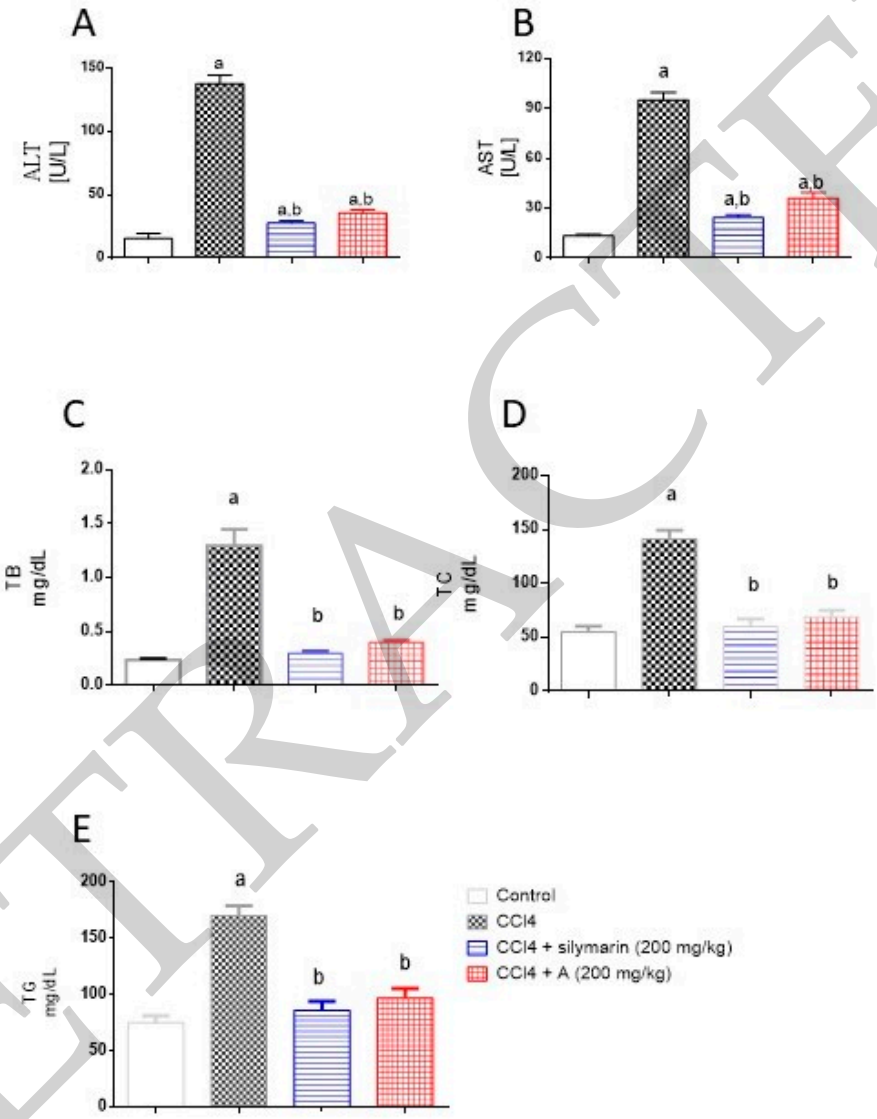


Figure 3. Influence of pretreatment with EAF on hepatotoxicity markers in a rat model of acute CCl_4 intoxication. (**A**) Alanine aminotransferase (ALT) activity, (**B**) aspartate aminotransferase (AST), (**C**) total bilirubin (TB), (**D**) total cholesterol (TC), and (**E**) triglycerides (TG). Statistical analysis was carried out by one-way ANOVA followed by Tukey post-hoc test ($n = 6$). a: Statistically significant from corresponding control at $p < 0.05$. b: Statistically significant from corresponding CCl_4-treated group at $p < 0.05$.

2.5. Effect of EAF on Liver Antioxidant Status

The observed in vitro antioxidant activity was further confirmed by assessing hepatic SOD activity, GSH, and MDA. Compared to control values, CCl_4 caused significant reduction of SOD activity, depletion of GSH, and accumulation of MDA. However, administration EAF prior to CCl_4

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injection normalized SOD activity and GSH content and ameliorated the rise in MDA in liver tissues. This antioxidant activity was comparable to those observed in silymarin-treated animals (Figure 4).

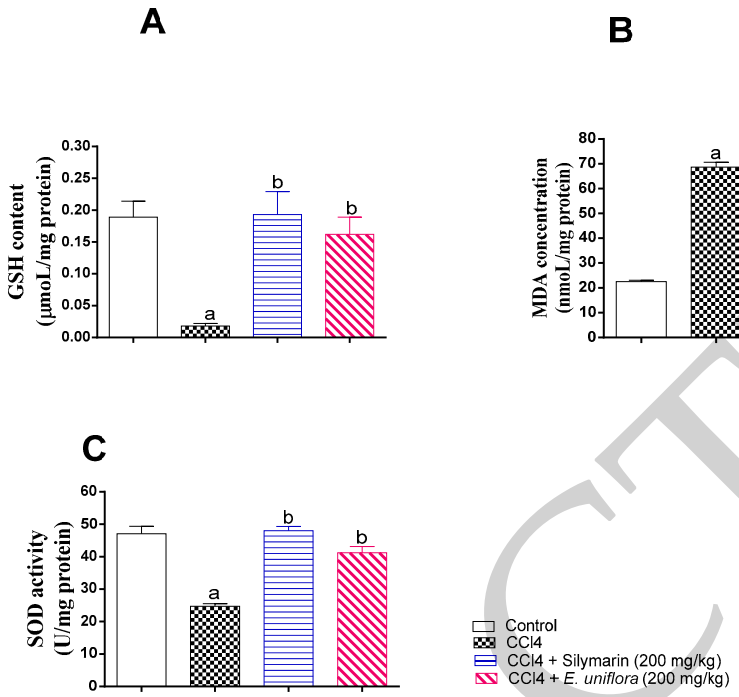


Figure 4. Influence of pretreatment of EAF leaves extract on markers of liver oxidative status in rats with acute CCl_4 intoxication. (**A**) Liver glutathione (GSH); (**B**) lipid peroxidation and generation of malondialdehyde (MDA); (**C**) superoxide dismutase (SOD). Statistical analysis was carried out by one-way ANOVA followed by Tukey post-hoc test ($n = 6$). a: Statistically significant from corresponding control at $p < 0.05$; b: statistically significant from corresponding CCl_4-treated group at $p < 0.05$.

2.6. Histopathological Investigation of the Liver

Hepatoprotective activity of EAF was additionally confirmed by histopathological examination of liver sections obtained from the different animals' groups. Figure 5A shows a section taken from a liver of a control rat showing normal hepatic architecture, hepatocyte structure, and central vein. In the CCl_4 treated group, the liver section shows dilated central vein with central hepatocellular necrosis and congested portal triad (Figure 5B). However, the section taken from a liver of rat pretreated with silymarin showed preserved hepatic architecture and only scattered cytoplasmic vacuolization (Figure 5C). In the fourth group, pretreatment with EAF effectively attenuated the CCl_4 -induced histopathological changes with a small number of hepatocellular vacuolization. Even though some congestion was observed with the appearance of hepatocellular necrosis in the central vein and portal triad, it occurred to a lesser extent than with CCl_4 intoxicated group (Figure 5D).

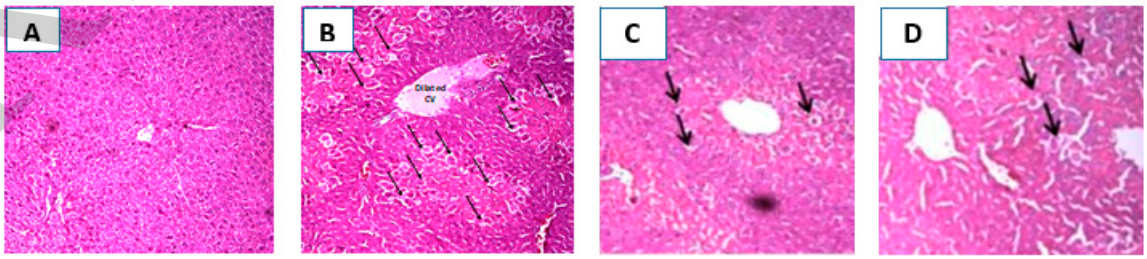


Figure 5. Representative photomicrographs of liver sections stained by hematoxylin & eosin (100×): (**A**): section taken from a liver of a control rat showing normal hepatic architecture, hepatocyte structure, and central vein; (**B**): section taken from a liver of a CCl_4-intoxicated rat showing dilated central vein

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with central hepatocellular necrosis (arrows) and congested portal triad; (**C**): section taken from a liver of rat pretreated with silymarin with preserved hepatic architecture and only scattered cytoplasmic vacuolization (arrows); and (**D**): section taken from a rat liver pretreated with EAF showing scattered cytoplasmic vacuolization (arrows).

3. Discussion

Liver diseases are among the major health problems that may be caused by toxic chemicals, medications, alcohol, or viruses [23]. Natural products with liver-protecting activities have obtained increasing attention. In particular, dietary polyphenols have impacts on many diseases, such as metabolic syndrome, obesity, and diabetes [24].

In the current work, EAF exhibited the highest activities in the DPPH assay and increased the survival rate in *C. elegans* via inducing nuclear localization of DAF-16::GFP, indicating that the in vivo antioxidant effect could involve the DAF-16/FOXO signalling pathway. These activities are attributed to the presence of several polyphenols, among them quercetin and myricetin glucosides. Our results are in agreement with a study by Durán et al. [25], where the authors reported that quercetin exhibits antioxidant activities in *C. elegans* that are DAF-16-independent. Additionally, another study by Büchter et al. revealed that myricetin exhibits antioxidant activities through nuclear translocation of DAF-16 [26].

Additionally, according to OCED-423 [27], EAF can be classified as category 5 with LD_{50} over 2000 mg/kg. This illustrates that the nonobservable adverse effect dose level EAF is above 2000 mg/kg. Based on this, the EAF dose was administered in the dose range of 200 mg/kg (one tenth of the limit test dose level) [28]. Hepatotoxicity induced by CCl_4 is the one of the most commonly used models for testing the hepatoprotective activity, as CCl_4 pathologic injuries in animals are closely similar to the symptoms of human liver disease. Hepatic cytochrome P450 metabolizes CCl_4 to highly reactive products in the liver, which contribute to lipid peroxidation and therefore impair hepatocyte functions and membrane permeability leading to enzyme leakage from hepatic cells into the bloodstream [21,29]. Liver function tests are used for assessing the liver's clinical condition. ALT and AST are widely used experimentally and clinically to determine live functions [30]. In the present study, the activities of ALT and AST as well as levels of TB, TC, and TG were significantly elevated in CCl_4-challenged animals. As expected, EAF prevented the rise in these markers and highlighted the potential hepatoprotective activity of the plant.

Our data indicate that CCl_4 caused accumulation of lipid peroxidation products, as indicated by MDA, suggesting tissue damage that exceeded physiological antioxidant defence mechanisms. Pretreatment with EAF ameliorated the rise in tissue content of MDA. SOD and GSH activities were significantly reduced after CCl_4 injection, confirming oxidative damage in the liver tissues. Pretreatment with EAF restored SOD and GSH activity. In line with these data, EAF prevented hepatic depletion of the natural antioxidant GSH, which was consistent with previous study that reported that *E. uniflora* showed the highest scavenging activity on the superoxide and DPPH radicals [31]. Furthermore, the observed hepatoprotective effects of EAF were supported by histopathological observations since pretreatment with EAF effectively attenuated the CCl_4-induced histopathological changes. Taken together, it can be concluded that the EAF of *E. uniflora* has a hepatoprotective effect against CCl_4-induced injury in rats.

These activities are attributed to the presence of several flavonoids such as quercetin, myricetin, apigenin, and kaempferol glucosides, which serve as powerful antioxidants in biological systems and have a wide spectrum of bioactivity. They minimize liver injury in association with lower lipid peroxidation [32,33]. It was reported that these flavonoids have anti-inflammatory effect [15,34] that can support the hepatoprotective effect of *E. uniflora*. It was also proved that myricetin inhibits P450s 2E1 and prevents the activation of CCl_4 into its active metabolite, trichloromethyl radical [35,36].

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The current results agree with those obtained from several plant species of the Myrtaceae. A study on the leaf extract from *Syzygium samarangense* revealed pronounced hepatoprotective effect. The extract consisted of 92 secondary metabolites belonging to flavonoids, phenolic acids, condensed tannins, and ellagitannins [19]. Another study performed on the leaf extract from *Syzygium jambos* demonstrated substantial antioxidant and hepatoprotective activities. The extract contained 17 phenolic compounds mainly myricetin 3-*O*-xylosyl-(1 → 2) rhamnoside [20]. Furthermore, a comprehensive study reported antioxidant and hepatoprotective activities in a polyphenol-rich leaf extract from *Syzygium aqueum* [21].

4. Materials and Methods

4.1. Plant Material, Extraction and Fractionation

Plant leaves were collected from Orman Botanical Garden, Giza, Egypt, and voucher specimen is kept at IPMB, Heidelberg University under accession number P8618. A sample (200 g) was extracted using methanol (3 × 0.5 L). The extracts were combined, evaporated, and freeze-dried yielding 25 g. The methanol extract was then suspended in water and partitioned by hexane, ethyl acetate, butanol, and the residue, yielding 1.4, 10.5, 6.9, and 3.5 g, respectively.

4.2. Liquid Chromatography–Mass Spectrometry (LC-MS) Analysis

A ThermoFinnigan LCQ-Duo ion trap mass spectrometer (ThermoElectron Corporation, Waltham, MA, USA) with an ESI source (ThermoQuest Corporation, Austin, TX, USA) was utilized. A Discovery HS F5 column (15 cm × 4.6 mm ID, 5 µm particles) (Sigma-Aldrich Co Steinheim, Germany) was used with the ThermoFinnigan HPLC system. The mobile phase was water and acetonitrile (ACN) (Sigma-Aldrich GmbH, Steinheim, Germany) (0.1% formic acid each). At 0 min, ACN was 5%, then increased to 30% over 60 min. The flow rate was kept at 1 mL/min with a 1:1 split before the ESI source. The MS operated in the negative mode as previously reported [37].

4.3. Antioxidant Activities In Vitro

DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) assay was carried out as described before [37].

4.4. Antioxidant Activities in Caenorhabditis elegans

The nematodes were maintained under the following conditions: 20 °C, on nematode growth medium (NGM), fed with living E. coli OP50. Age synchronized cultures were obtained by treating gravid adults with sodium hypochlorite. The eggs were kept in M9 buffer for hatching, and the larvae were transferred to S-media seeded with living E. coli OP50 (O.D.600 nm = 1.0). The C. elegans strains such as wild-type (N2) and TJ356, were obtained from the Caenorhabditis Genetic Center (CGC). The in vivo assays, including survival rate and DAF-16, were done according to our previous description [38].

4.5. In Vivo Antioxidant and Hepatoprotective Assessment

4.5.1. Rat Experiments

The study was conducted on male Wistar rats, weighing 200–250 g, obtained from the animal facility, King Abdulaziz University, Jeddah, KSA. The rats were housed in an air-conditioned atmosphere at 22 ± 2 °C, under a 12 h light–dark cycle. Protocol for animal handling was approved by the Unit of Biomedical Ethics Research, Faculty of Medicine, King Abdulaziz University.

4.5.2. Acute Oral Toxicity Study

The acute oral toxicity of EAF was evaluated in line with the Organization for Economic Cooperation and Development-423 (OCED) [27] to determine the Oral LD_{50} of EAF. OCED-423 stated that a limit test at one dose level of 2000 mg/kg body weight may be carried out with six animals

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(three animals per step), and if test substance-related mortality is produced, further testing at the next lower level may need to be carried out. Here, we performed the test twice with the use of three male Wistar rats in each time. The animals received a dose of EAF (2000 mg/kg by gavage).

4.5.3. Experimental Design

After acclimatization, rats were randomly allocated into four groups (six rats each) and the groups were treated as follows: Group # 1: Rats served as control and were treated by gavage with water followed by corn oil (1 mL/kg; i.p.) 4 h. later. Group # 2: Rats were injected once with CCl_4-corn oil 50% mixture (1 mL/kg; i.p.). Group # 3: Rats served as a positive control and were pretreated with silymarin (200 mg/kg; p.o.) for 7 days followed by a single dose of CCl_4-corn oil 50% mixture (1 mL/kg; i.p.). Group # 4: Rats were pretreated with the EAF (200 mg/kg; p.o.) for 7 days followed by a single dose of CCl_4-corn oil 50% mixture (1 mL/kg; i.p.). The dose of CCL_4, silymarin, EAF, and the duration of treatment were guided by previous publications [28,39,40], as well as a preliminary experiment in our laboratory. At the end of the experiment, the rats were fasted for overnight and anesthetized with ketamine (6.6 mg/kg, i.p.) and xylazine (0.3 mg/kg, i.p.). Then, rats were sacrificed by decapitation.

4.5.4. Blood Sampling and Tissue Preparation

Blood samples were collected by cardiac puncture and allowed to clot. Sera were separated by centrifugation at 3000 rpm for 10 min, and then kept at −80 °C for subsequent analyses. After rat scarification, livers were rapidly dissected out. Representative tissue from each lobe was cut and fixed in 10% neutral buffered formalin and then embedded in paraffin for histopathological examination. The remaining liver tissues were reweighed, washed, and homogenized (10% *w*/*v*) in ice-cold Phosphate buffered saline (PBS). Liver homogenates were then kept at −80 °C until needed.

4.5.5. Biochemical Analyses

Serum activities of ALT and AST and levels of total bilirubin (TB), total cholesterol (TC), and triglycerides (TG) were determined colorimetrically using Mindray BS-120 clinical chemistry auto-analyzer (Shenzhen Mindray Bio-medical Electronics Co. Ldt., Shenzhen, China). Concentrations of reduced glutathione (GSH), and malondialdhyde (MDA) and activity of superoxide dismutase (SOD), were determined using commercially available kits (Biodiagnostics, Cairo, Egypt).

4.5.6. Histopathological Examination

Tissue samples were fixed in 10% neutral buffered formalin for 24 h. After rehydration in serial dilutions of methyl, ethyl, and absolute alcohol, specimens were cleared in xylene and embedded in paraffin at 56 °C in a hot air oven for 24 h. Paraffin tissue blocks were sectioned to 4 μm thickness. The obtained tissue sections were collected on glass slides, deparaffinized, and stained with hematoxylin and eosin. Six fields were randomly selected for analysis from each tissue section from each rat. Sections were examined using a light microscope (Olympus BX-50 Olympus Corporation, Tokyo, Japan).

4.5.7. Statistical Analysis

Data are presented as mean and S.D. One-way analysis of variance (ANOVA) was used to compare means, and Tukey's test was used post hoc analysis. Statistical significance was acceptable to a level of $p < 0.05$. All statistical analyses were performed using GraphPad Prism software, version 6.00 (GraphPad Software, Inc. La Jolla, CA, USA).

5. Conclusions

LC-MS analysis of the ethyl acetate fraction of *Eugenia uniflora* leaves revealed 22 secondary metabolites, including quercetin, myricetin, apigenin, and kaempferol glucosides. The ethyl acetate fraction exhibited solid antioxidant activities in vitro in the DPPH assay and counteracted the oxidative stress against

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the lethal dose of juglone in the model organism *C. elegans* via activation of DAF-16 transcription factor. Furthermore, EAF demonstrated substantial hepatoprotective activities and ameliorated the deleterious effects of CCl_4 in rats. These results provide good evidence to consider *Eugenia uniflora* as a plant of biological importance and a valuable source for antioxidant and hepatoprotective agents.

Author Contributions: M.S. performed the extraction, chemical characterization of the extract, and the antioxidant activities; analyzed the data; wrote the paper; and conceived and designed the project. M.S.H. and A.B.A.-N. designed and performed the hepatoprotective experiments and wrote the paper. M.L.A., M.E., and M.A.E.R. participated in the chemical characterization of the extract, analyzed the data, and revised the manuscript. M.W. revised the paper and conceived and designed the project. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

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