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ISOLATION AND BIOLOGICAL PROPERTIES OF LAWSONE: A REVIEW

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ABSTRACT:
Lawsone also known as hennotannic acid, is a red-orange dye present in the leaves of the henna plant (*Lawsonia inermis*). The present review was based on the isolation and biological properties of lawsone. Lawsone is a 1,4-naphthoquinone derivative of hydroxyquinone containing one additional ring. It has a characteristic purple/brown coloration as opposed to the purple/blue associated with ninhydrin. Quinones are widely-distributed aromatic compounds present throughout nature, and can be found in several families of plants, as well as isolated of fungi, algae and bacteria. Hydroxynaphthoquinones have proved effective due to their chemical and pharmacological properties. Naphthoquinones are compounds present as secondary metabolites of plants and microorganisms; they confer activity in various biological oxidative processes and represent a chemical defence used by many plants. Lapachol, lawsone, juglone and plumbagin are examples of natural naphthoquinones isolated from plants, and can be distinguished by their use in traditional Indian medicine. In conclusion, lawsone and *Lawsonia inermis* have demonstrated for various pharmacological properties i.e., antifungal, antibacterial, effects on CNS, analgesic, anti-inflammatory & anti-pyretic, hepatoprotective, anti-parasitic, abortifacient, anti-urolithiasis, antidiabetic & hypolipidemic effects, anti-ulcer, wound healing, diuretic, anti-diarrhoeal, anticancer and antioxidant.

Keywords: Lawsone, habitat, isolation, biological properties, anticancer.

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INTRODUCTION

Lawsone also known as hennotannic acid, is a red-orange dye present in the leaves of the henna plant (*Lawsonia inermis*). Lawsone reacts chemically with the protein keratin in skin and hair via a Michael addition reaction, resulting in a strong permanent stain that lasts until the skin or hair is shed. Darker colored staining is due to more lawsone–keratin interactions occurring, which evidently break down as the concentration of lawsone decreases and the tattoo fades. Lawsone strongly absorbs UV light, and aqueous extracts can be effective sunless tanning agents and sunscreens [1].

Lawsone is a 1,4-naphthoquinone derivative of hydroxyquinone containing one additional ring. Lawsone non-specifically targets primary amino acids, and displays photoluminescence with forensic light sources. It has a characteristic purple/brown coloration as opposed to the purple/blue associated with ninhydrin. Lawsone shows promise as a reagent for fingerprint detection because of its photoluminescence maximized at 640 nm, which is high enough that it avoids background interference common for ninhydrin [2][3].

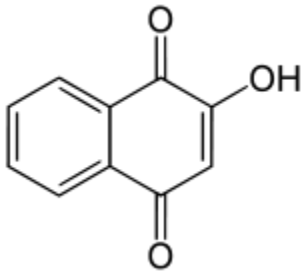

Fig 1. Structure of Lawsone

The molecular formula of lawsone is C10H6O3 and its melting point is 190°C. It is present in three tautomeric forms; the 1,4-naphthoquinone structure is the most stable [4] form followed by 1,2-naphthoquinone [5] and 1,2,4-naphthotrione; the trione system is the least stable but is probably in equilibrium in solution with the other two tautomeric forms. This stability is due to cancelation of dipolar moments of carbonyl groups, in combination with intramolecular hydrogen bonds in the 1,4 isomers [6].

Description and Sources

Quinones are widely-distributed aromatic compounds present throughout nature, and can be found in several families of plants, as well as isolated of fungi, algae and bacteria. Quinones are classified into benzoquinones, anthraquinones and naphthoquinones according to their chemical structures [7]. Naphthoquinones are structurally related to naphthalene and are characterized by their two carbonyl groups in the 1,4 positions, and as such, are named 1,4-naphthoquinones. Carbonyl groups may also be present at the 1,2 positions, with minor

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incidence. Naphthoquinones are highly reactive organic compounds, used as natural or synthetic dyes whose colors range from yellow to red. These compounds and their derivatives are α,β-unsaturated carbonyl compounds. The conjugation between carbonyl and double bonds give rise to 1,4-naphthoquinone, which has an intense coloration [8].

Hydroxynaphthoquinones have proved effective due to their chemical and pharmacological properties. An important derivative is 2-hydroxy-1,4- naphthoquinone, also known as lawsone [9]. Lawsone is the principal active ingredient of the henna plant [10]. Henna is a fine powder of a brown-green color. Henna plants are tall flowering shrubs or trees that are about 2–5 m in height, and are native to tropical and subtropical regions of Africa, India, Sri Lanka and the Middle East. Lawsone was first isolated from the leaves of Lawsonia inermis in 1959. Young henna plants do not have spines, and the amount of lawsone obtained from these plants is poor in comparison to mature plants that have spines. 2-Hydroxy-1,4-naphthoquinone is the main natural dye (red-orange) in the leaves of henna plants, present at a concentration of 1.0–1.4% w/w. Humans have used extracts containing lawsone henna as a cosmetic dye for both skin and hair for over 5000 years [11]. Thus, lawsone has been reported since around 1890 and it has been extensively distributed in Europe; today is widely available in markets around the world in the form of dyes or hair care products.

Isolation

Naphthoquinones are compounds present as secondary metabolites of plants and microorganisms; they confer activity in various biological oxidative processes and represent a chemical defense used by many plants. Lapachol, lawsone, juglone and plumbagin are examples of natural naphthoquinones isolated from plants, and can be distinguished by their use in traditional Indian medicine [12]. As well as their dye properties, hydroxy-1,4-naphthoquinones and their derivatives have been shown to have important biological activities, such as antimalarial, antibacterial, antifungal and anticancer properties. Among the natural hydroxynaphthoquinones are: lawsone, which can be obtained from the leaves and stems from henna (Lawsonia inermis); plumbagin, which is mainly extracted from the roots of Plumbago scandens and is used for the treatment of leprosy and tuberculosis; lapachole, which can be isolated from the heartwood of plants of the genus Tabebuia spp., Tecoma spp. and Tecomella undulata; juglone, obtained from the roots, leaves, nuts, bark and wood of black walnut (Juglans nigra), European walnut (Juglans regia) and American white walnut (Juglans cinerea); naphthazarin, which is naturally produced in the wood bark tree Lomatia obliqua and Alkana species; mompain, isolated from the fungi Helicobasidium mompa; shikone, which is the mayor constituent of red extracts from the roots of the plant Lithospermum erythrorhizon; and the alkaline enantiomer is found in the roots of Alkanna tinctoria [13].

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Biological Properties

Antifungal

Henna leaves have a bitter flavor and have been used in traditional medicine as an astringent, antiseptic and antipyretic. Henna has been used for years by Islamic doctors in the treatment of various diseases such as leprosy, smallpox, chickenpox and tumors. Lawsone isolated from lawsone leaves showed significant antifungal activity against Candida albicans [14].

Antibacterial

2-Hydroxy-1,4-naphthoquinone and its derivatives have been reported to possess important activities. Rahmoun et al. reported the antibacterial activity by the disk diffusion method of 2-hydroxy-1,4- naphthoquinone derivatives. Two compounds with chloride and nitro substituents were active against S. aureus ATCC 25923 with MIC values of 16–32 µg/mL and 32–64 µg/mL, respectively [15].

Antiparasitic Activity

Researchers reported the synthesis of 2-hydroxy-1,4-naphthoquinone derivatives and evaluated their effectiveness against the brine shrimp Artemia salina and against the mollusk Biomphalaria glabrata, which is the main transmitting vector of schistosomiasis in Brazil. Of the seventeen compounds tested, nine fell below the threshold of 100 µg/mL set by the World Health Organization for potential molluscicidal activity (59). Other interesting synthetic naphthoquinones reported by Baramee et al. (2006) are ferrocenyl aminohydroxynaphthoquinones, which showed antiparasitic activity against Toxoplasma gondii [15].

Antioxidant

In 2010, Vinothkumar et al. reported the in vitro antioxidant activities of hydroxyl-1,4-naphthoquinone; these compounds were tested and evaluated by the amount of scavenged radical method. The entire synthesized compound exhibited a moder ate antioxidant activity particularly for the DPPH radical parameter, and the researcher also showed that the compound had appreciable lipid peroxidation activity [16].

Naphthoquinones interact with biological targets by forming covalent bonds or via their ability to undergo reversible oxidation-reduction reactions. The mechanism of action usually involves the generation of reactive oxygen species (ROS) by the redox cycle under aerobic conditions, by the inhibition of electron transport, by DNA intercalating and/or alkylating agents of biomolecules, and/or as topoisomerase inhibitors. In all of the mechanisms of action in vivo, bio reduction is required as a first step in quinone formation. In general, the biological activity of the naphthoquinone involves the ability to accept one or two electrons

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to form anion radicals (semiquinone) and dianion (hydroquinone) respectively. These anions are highly reactive [17].

Antimalarial

A chemically characterized extract and its major constituent were investigated for *in vitro* antiplasmodial activity on chloroquine-sensitive NF-54 strain. The ethyl acetate extract of leaves (IC_{50} 9.00±0.68µg/ml) and fraxetin (IC_{50} 19.21±1.04 µM) were the most effective in *in vitro* assays and they were further selected for *in vivo* in *Plasmodium berghei* infected mice. The administration of the ethyl acetate extract of leaves and fraxetin to the infected mice resulted in significant ($p < 0.05$) suppression of parasitemia as evidenced by a 70.44±2.58% to 78.77±3.43% reduction. A two-fold increase in mean survival time, a significant ($p < 0.05$) reduction in lipid peroxidation and an elevation in glutathione, catalase, and superoxide dismutase were also observed in treated mice. The post-infection treatment also augmented the endogenous antioxidant enzymes compared with infected control [18].

Antileishmanial

The antileishmanial effect of *Lawsonia inermis* methanolic extracts (0.07, 0.15, 0.31, 0.62, 1.25, 2.5, 5, 10 mg/ml) was studied on *Leishmania major* promastigotes using the MTT assay. *Lawsonia inermis* methanolic extract inhibited the growth of promastigote forms of *L. major in vitro* after 72 h of incubation and showed IC_{50} of 1.25 mg/ml [19].

Anti-trypanosomal

The antitrypanosomal activity of *Lawsonia inermis* leaves was investigated *in vitro* and *in vivo*. the crude methanolic extract of *Lawsonia inermis* leaves had *in vitro* activity against *Trypanosoma brucei* at concentration of 8.3 mg/ml while *in vivo* study revealed that the methanolic extract of *Lawsonia inermis* leaves ameliorated the disease condition but did not affect the level of parasitaemia and pack cell volume [20]. The ameliorative effect of methanol leaf extract of *Lawsonia inermis* (125, 250 and 500 mg/kg, orally) was studied in rats infected intraperitoneally with 106 *Trypanosoma congolense* per ml of blood. The extract significantly ($p<0.05$) reduced levels of parasitaemia at 250 mg/kg, increased PCV ($p>0.05$) and significantly decreased EOF and MDA. The authors concluded that, in addition to an antitrypanosomal effect of of *Lawsonia inermis* against *T. congolense* in rats, it attenuated the trypanosomosis pathology probably via protection of the erythrocyte membrane against trypanosome-induced oxidative damage to the erythrocytes.

Larvicidal

The larvicidal activity of *Lawsonia inermis* (4, 40, 400 and 4000 ppm) was studied against, the malaria vector, *Anopheles stephensi*. The highest toxic effect of *Lawsonia inermis* was

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found at 4000 ppm and the lowest at 4 ppm against larval stages I and II. The same result was found against larval stages III and IV. The LC_{50} and LC90 were 413.8, 3366.3, 696.9 and 3927.7 ppm respectively against larval stages I, II, III and IV stages [21]. The larvicidal effects of the methanolic extracts of 11 medicinal plants were investigated against malaria vector, *Anopheles stephensi*. The methanolic extract of aerial parts of *Lawsonia inermis* showed high larvicidal activity with LC_{50} value of 69.40 ppm [22].

Molluscicidal Action

Molluscicidal activity of Leaf, bark and seed of *Lawsonia inermis* was tested against *Lymnaea acuminata* and *Indoplanorbis exustus.* Seed powder was more toxic than leaf and bark against *I. exustus.* Binary combinations of henna seed with *Cedrus deodara* and *Azadirachta indica* oil, powdered *Allium sativum*, or *Zingiber officinale* rhizome oleoresin revealed more toxicity to snails *L. acuminata* and *I. exustus* than their single treatment. The combination with neem oil was also more toxic than their individual components and other combinations [23].

Hepatoprotective

The *in vitro* antioxidant and *in vivo* hepatoprotective potential of butanolic fraction of *Lawsonia inermis* leaves (100, 200 and 400 mg/kg bw) was studied against 2-acetylaminofluorene (2-AAF) induced hepatic damage in male Wistar rats. Butanoic fraction effectively scavenged hydroxyl radicals in deoxyribose degradation assay (IC_{50} 149.12 µg/ml). It also inhibited lipid peroxidation and caused appreciable reducing potential in FRAP assay. Different concentration of butanoic fraction showed pronounced hepatoprotective effects via decreasing levels of SGOT, SGPT, ALP and lipid peroxidation altered by 2-AAF treatment. It also restored the normal liver architecture as evident from hepatoprotective effect [24]. The hepatoprotective efficacy of lawsone, the major bioactive naphthoquinone present in *Lawsonia inermis* was studied in RIF-INH exposed HepG2 cells, and RIF-INH induced hepatotoxicity in Wistar rats. Administration of RIF-INH reduced the viability of the HepG2 cells and the treatment with lawsone significantly restored the viability of the cells even at lower concentration (7.5 µM), the leakage of transaminases and MDA levels were also significantly reduced by the treatment with lawsone. Treatment with lawsone to the RIF-INH administered animals significantly lowered the serum transaminases and bilirubin, levels and improved the ratio of albumin to globulin [25].

Effects on CNS

The psychopharmacological activity of methanolic extract of *Lawsonia inermis* (50, 100 and 200 mg/kg) was studied in albino mice using staircase test. The methanolic extract of *Lawsonia inermis* at 100mg/kg drastically augmented the number of steps up in the

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Staircase with peak activity procured at the dosage of 100 mg/kg (37.8±4.2 seconds) compared to control (6.3±2.2 seconds). The extract at dosage of 100 mg/kg notably accelerated the number of steps up with peak effect at the dosage of 100 mg/kg (37.8±4.2 seconds) compared to control (6.3±2.2 seconds) [26].

The methanolic extract of *Lawsonia inermis* was tested for anxiolytic potential using white dark box model in mice. The extract at a dose of 100 mg/kg ip, exhibited a significant increase in time spent in light area with respect to control animals. The reduction in anxiety behavior, also demonstrated by significant increase in number of entries in the light compartment relative to the dark compartment of the testing apparatus. The effect of acute and chronic administration of aqueous extract of *Lawsonia inermis* leaves (100, 200 and 400 mg/kg) was investigated on haloperidol (1mg/kg, ip) induced catalepsy in albino mice as an animal model for Parkinson's disease (PD). Extract caused significant reduction in the cataleptic scores and increase in SOD activity, the maximum reduction was observed in chronic administration of a dose of 400 mg/kg bw [27].

Analgesic, Anti-Inflammatory and Anti-Pyretic

The analgesic and anti-inflammatory effects of the mixture of *Lawsonia inermis* leaves with aqueous extract of *Ricinus communis* leaves was studied in rats with induced knee osteoarthritis. The knee osteoarthritis was induced by intra-articular injection of mono sodium iodoacetate. The mixture of extracts significantly reduced the knee joint width and volume of the injected paws and also improved foot prints in gait analysis after 3 d of injection. Analysis of mechanical allodynia after 21 d, hotplate latency test after 10 d, spontaneous movements after 7 d and in mechanical allodynia after 14 d, showed significant analgesic effects compared to the vehicle group. The formulation also made significant therapeutic histopathological changes on the knee of the rats [28].

The crude ethanolic extract of *Lawsonia inermis* (0.25-2.0 g/kg) produced significant and dose-dependent anti-inflammatory, analgesic, and antipyretic effects in rats. The butanol and chloroform fractions showed more potent anti-inflammatory, analgesic, and antipyretic effects than the crude extracts, the butanolic extract (500 mg/kg) was the most effective in the analgesic test. A pure compound was isolated from the chloroform extract (2-hydroxy-1,4-naphthaquinone, lawsone) which possessed significant anti-inflammatory, analgesic, and antipyretic activity. The anti-inflammatory effect of lawsone (500 mg/kg) was not significantly different from that of the reference drug, phenylbutazone (100 mg/kg) [29].

Wound Healing

The wound healing activity of the ethanol extract of *Lawsonia inermis* (200 mg/kg/day) was studied in rats using excision, incision and dead space wound models. The extract treated animals showed a high rate of wound contraction ($p<0.001$), a decrease in the period of

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epithelialization ($p<0.001$), high skin breaking strength ($p<0.001$), significant increase in the granulation tissue weight ($p<0.001$) and hydroxyproline content ($p<0.05$) compared with the control group. The extract-treated animals showed 71% reduction in the wound area when compared with controls. Histological studies of the tissue obtained on day 10 from the extract-treated group showed increased well-organized bands of collagen, more fibroblasts and few inflammatory cells when compared with the controls [30].

Wound healing potential of different extracts of *Lawsonia inermis* leaves and lawsone was studied in rat excision and incision wound models. Oral administration and topical application of ethanol extract of henna leaves and lawsone exhibited significant healing response in both wound models. The ethanol extract, as well as lawsone topically, were more effective than their oral uses [31].

Abortificient Effect

The abortificient effect of *Lawsonia inermis* extract was studied in the pregnant mice. 1 and 10 mg/kg bw of the hydroalcoholic extract of *Lawsonia inermis* were injected intraperitoneally into pregnant mice from the first to the seventeenth day of pregnancy. Abortions were observed more often in the *Lawsonia inermis* treated groups ($p<0.01$) with significantly higher mean of the serum estrogen ($p<0.01$) and the significantly lower mean of progesterone level ($p<0.01$) [32].

Immunomodulatory Effect

The methanolic extract of henna leaves at 1 mg/ml concentration possessed immunomodulatory evidenced by stimulation of T-lymphocyte proliferative responses. Naphthoquinone obtained from leaves also showed significant immunomodulatory effect [33].

Gingivitis Healing Activity

The effectiveness of *Lawsonia inermis* leaves methanol extracts (62.500, 31.250, and 15.625 µg/ml) in healing gingivitis was studied in Sprague Dawley rats with induced artificial inflammation in the mandibular labial gingiva by 10% H2O2. There was no difference in healing between the three concentrations of *Lawsonia inermis* leaves methanol extract and povidone-iodine, while there were differences among the 3 concentrations. Higher concentration (62.500 µg/ml) can accelerate the inflammatory cells reduction and epithelial connective tissue repair [34]. The effect of *Lawsonia inermis* leaves infusion in gingivitis healing was studied clinically. Sixty-three gingivitis patients were instructed to rinse with 3 concentrations (50000, 10000 and 5000 µg/ml) of *Lawsonia inermis* leaves infusion, 0.1% hexetidine solution, and placebo as control. Bleeding index was decreased in *Lawsonia*

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inermis leaves infusion at 10000 µg/ml concentration (80%), more than hexetidine 0.1% (76%) [35].

Anti-Urolithiasis Activity

The curative and protective effects of the alcoholic extract of *Lawsonia inermis* bark against ethylene glycol induced urolithiasis and its possible underlying mechanisms were studied in rats. Methanolic extract of *Lawsonia inermis* (MELI) bark (300 and 500 mg/kg, po) were administered once daily from 15th day to 28th day as curative regimen and from 1st day to 28th day as a preventive regimen. Treatment with the extract significantly restored all elevated parameters including calcium, phosphate and oxalate in urine and kidney homogenate; and creatinine, uric acid and urea nitrogen in serum compared to the control group. The histopathological study of the kidney also supported the biochemical results [36].

The anti-urolithiatic activity of hydroethanolic extract of the leaves of *Lawsonia inermis* was studied in ethylene glycol with ammonium chloride model in rats. Hydroethanolic extract showed significant antiurolithiatic activity against calcium oxalate type stone. It modulated the levels of serum urea, urea nitrogen, uric acid, creatinine, kidney weight, urine volume, urine PH, urinary total protein, calcium, phosphorus, and magnesium [37].

Antidiabetic and Hypolipidemic Effects

The hypoglycemic and hypolipidemic effects of *Lawsonia inermis* hydroalcoholic extract (100, 200 and 400 mg/kg) were studied in alloxan-induced diabetic dyslipidemia in rats. The percentage reduction in blood glucose level of *Lawsonia inermis* hydroalcoholic extract at dose of 400 mg/kg was 39.08% on day 21 compared to baseline, which was comparable to glibenclamide (44.77%) and metformin (46.30%). The hypoglycemic effect of the extract exhibited significant improvement in lipid profile, plasma albumin, total plasma protein and serum creatinine [38].

The antidiabetic effect of methanolic extracts of *Lawsonia inermis* was determined by quantitatively determining the maltose from the maltose standard curve. The methanolic leaves extract of the plant significantly inhibited the enzymatic activity of the amylase at 10 µg/m dose (60.97% compared to untreated, $p<0.05$). The effect of 70% ethanol extract of *Lawsonia inermis* leaves on glucose, total cholesterol and triglyceride were studied in alloxan induced diabetes in mice. The results showed that the feeding of 0.8 g/kg bw of the extract decreased the glucose concentration from 194 mg/dl to normal condition after 14 d. The total cholesterol concentration decreased from 148.9 mg/dl to 55.3 mg/dl, while triglyceride concentration decreased from 225.7 mg/dl to 76.9 mg/dl [39].

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Antiulcer Effects

The antiulcer effects of aqueous, chloroform and ethanol extracts of henna leaves (200 and 400 mg/kg) was studied in rats pylorus ligation and aspirin-induced ulcer. In aspirin induced ulcers, the chloroform extract showed significant reduction of ulcers in a dose dependent manner. However, the results showed that aqueous, ethanol and chloroform extract significantly ($p<0.001$) decreased the volume of gastric acid secretions, free acidity and total acidity and ulcer index [40].

Anti-Diarrhoeal Effects

The ethanol extract of the leaf of *Lawsonia inermis* was examined for anti-diarrhoeal properties using the castor oil induced diarrhea model in mice. The ethanol extract at a dose of 500 mg/kg possessed anti-diarrhoeal activity compared to the control group and offered about 1.398 of the mean latent periods for the diarrhoeal episode ($p<0.002$) [41].

Diuretic Activity

The diuretic activity of aqueous and ethanolic extracts (250 and 500 mg/kg, orally) of *Lawsonia inermis* leaves was investigate in rats. Both extracts of leaves showed significant diuresis, ethanolic extract showed more activity than aqueous extract. Urine volume in rats treated with aqueous extract of *Lawsonia inermis* at low and high doses were 4.6 ml and 6.1 ml respectively, while, urine volume in rats treated with ethanolic extract at low and high dose were 7.3 ml and 9.0 ml respectively. The concentrations of Na+, K+ and Cl- in rats treated with aqueous extracts at low dose were 113.8, 66.60 and 127.3 mEq/l respectively, and high dose 127.8, 73.60 and 155.6 mEq/l respectively, while, the concentrations of Na^+, $K^+$and Cl^-in rats treated with ethanolic extracts at low dose were 120.5, 71.20 and 147.5 mEq/l respectively, and high dose 136.2, 89.13 and 170.5 mEq/l respectively [42].

Anticancer

The antitumor effect of ethanol extract of root of *Lawsonia inermis* (180 mg/kg of bw for 15 d) was investigated against Dalton's lymphoma ascites (DLA) bearing mice. Treatment with *Lawsonia inermis* extract improved the liver and kidney function and rearranges more or less normal architecture. The extract also increased the number of the WBC count, platelets, lymphocytes, the pathophysiological marker enzyme and lipid profile and decreased the number of the RBC count, hemoglobin content, monocytes, the enzymic and non enzymic antioxidants [43].

The cytotoxic effect of the extracts of *Lawsonia inermis* was studied against human colon cancer cell lines (Caco-2), liver cancer cell lines (HepG2), hormone-dependent breast cancer cell lines (MCF-7) and hormone-independent breast cancer cell lines (MDA-MB-231) and Chang Liver cell lines using MTT assay. The chloroform extract of henna was active against

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human colon cancer cell lines (Caco-2) and liver cancer cell lines (HepG2) with an IC_{50}-value of 25.1 and 28 µg/ml, respectively. The cytotoxic mechanism was studied by determining the effect of the extract on the c-myc gene expression. It caused down-regulation of c-myc expression [44]. The anticarcinogenic potential of 200 and 400 mg/kg bw of 80% ethanolic extract of the fresh leaves of *Lawsonia inermis* was studied using benzo (a) pyrene-induced forestomach and 7,12 dimethylbenz (a)anthracene (DMBA)-initiated and croton oil-promoted skin papilloma genesis. The chemopreventive response was measured by the average number of papillomas per mouse (tumor burden) as well as percentage of tumor-bearing animals and tumor multiplicity. There was a significant inhibition of tumor burden in both studied tumor model systems ($p<0.01$ to $p<0.001$). Tumor incidence was also reduced by both doses in both the model systems [45].

CONCLUSION

It concludes that naphthoquinones are a promising group of compounds, as shown by the wide variety of biological activities described in the above literature review. 1,4-naphthoquinone and its derivatives are widely distributed in nature and have been used since ancient times in traditional medicine. Lawsone, one of the hydroxy derivatives of 1,4-naphthoquinone, has been used as a dye, and both its natural form and synthetic derivatives exhibit antibacterial, antifungal, antimalarial, anti-tumor, molluscicidal and antioxidant activity, among others. One way to synthesize amino derivatives such as lawsone, is through the Mannich reaction, as being simple, environmentally benign, economical, fast and efficient. Hydroxynaphthoquinone derivatives are promising compounds for treating disease and/or for pest control.

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CONFLICT OF INTEREST

Authors declared for none conflict of interest.

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