**ERUCA SATIVA LINN.: PHARMACOGNOSTICAL AND PHARMACOLOGICAL PROPERTIES AND PHARMACEUTICAL PREPARATIONS**

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**ABSTRACT**

*Eruca sativa* (jarjeer) is an annual herb (family Brassicaceae), which contains a wide range of chemicals and minerals with nutraceutical and organoleptic characteristics. Jarjeer was generally used as food and traditionally mainly consumed due to its aphrodisiac properties. This crop known to contain various phytochemicals such as flavonoids, phenolic acids, terpenoids, tannins, glycosides, saponins, steroids, alkaloids, and other secondary metabolites. Leaves, kaempferol and its derivatives, glucosativin, are the main flavonoids and glucosinolate, respectively, while erucic acid and glucoerucin are the main fatty acid and glucosinolate, respectively. Medicinally, the plant has antibacterial, antidiabetic, antihypertensive, antiproliferative, and antioxidant activity and stimulates hair growth and other effects. Trails on topical pharmaceutical preparations involve the use of *E. sativa* which had been done. These preparations include creams and waxes which are intended to be used for potentiating hair growth and skin fungal and bacterial infections.

**Keywords:** Eruca sativa, Jarjeer, Erucin, Aphrodisiac, Pharmaceutical preparation, Cream, Wax.

**INTRODUCTION**

*Eruca sativa* is commonly known as rocket plant. The local Iraqi and Jordanian name is jarjeer [1,2]. Rocket is a member of mustard (Brassicaceae) family [3,4], originated in the Mediterranean region coast, also grown in the Middle-East, South Asia, and all over the world [5,6]. The airy tender fresh parts of plant was used in salad and occasionally cooked as a potherb [7,8], also as spice, and as a medicinal remedy for various diseases [9]. Conventionally, the plant consumed as tonic, rubefacient, astringent, digestive, laxative, emollient, stimulant, stomachic, scurvy, to increase sexual desire (aphrodisiac) [10,11] and diuretic [10,12]. Jarjeer seeds known to have high oil, protein, and glucosinolate content [13]. Taramira oil, the traditional spice, is produced from seeds [5]; erucic acid (long chain fatty acid) is the major constituent of taramira oil. Other constituents of taramira oil are oleic acid, linoleic acid, and saturated fatty acids. Taramira oil is used to sooth the skin, massage, soap production, and cooking, for salad, and as an adulterant for mustard oil to impart spicy taste to the latter. The tender leaves and shoots harvested 20–30 days after germination and then consecutively cultivated from regrowth [4,6,25,26]. *E. sativa* has a gaunt taproot, erect, rigid, and little branching hairy stem. Leaves have dull or faint green color, deeply cut, compound lobular shaped, rather fleshy, hairy, 5–15 cm long, “The basal leaves are petiolate (have a stem), and pinnately lobed or divided. They are somewhat pointed, lance-shaped, and deeply indented near the plant base. Leaves found along the stem are smaller” and have distinctive pungent or spicy flavor. Flowers are bisexual, white in color with purple veins, few in number, large in size, 2–4 cm in diameter, and borne on small terminal racemes. Flowers have erect sepals and the petals taper to a lean claw.

Fruits are cylindrical siliquae in shape with a flattened beak 3–4 mm long. Seeds are spherical or ovoid extended from 1.5 to 2 mm, pale brown to olive green shade, and set in to 2 or 3 rows on each side [6,27-29].

**PHYTOCHEMISTRY**

Abroad range of phytochemicals had been identified in *E. sativa* leaves and seeds such as fatty acids, terpenoids, phenolics, carbohydrate, alkaloid, glycosides, saponins, steroids, and others [9,17,18,30,31]. Gas chromatography–mass spectrometry (GC-MS) analysis of petroleum ether seed extract revealed the presence of seven fatty
acids. These include myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid, erucic acid, and oleic acid [9,32-34]. In addition to previously mentioned compound, cosaenoc acid C20(3), and nervonic acid C24(1), acid and nervonic acid had been identified by gas-liquid chromatography (GLC) in Egyptian seed extract [35].

Meanwhile, the fatty acid detected by GC-MS analysis of saponifiable fraction of hexane leaf extract demonstrates the presence of different fatty acids, and the main acids that present in higher percentage are palmitic acid, azelaic acid, trace-vaccenic acid (C18H34O2), and palmitoleic acid [36]. That linolenic acid constitutes 48% of the fatty acid composition of rocket [32,37].

Cholesteral, secocholester-1(10)-en-3, 5-dione, β-sitosterol, and stigmasteral were detected by GC-MS analysis of unsaponifiable fraction of hexane leaf extract [36]. Campesterol and brassicasterol were also detected in E. sativa [38-40].

In seeds, β-sitosterol, cholesteral, stigmasterol, and campesterol were detected in unsaponifiable fraction of extract by GC-MS [35].

Volatile constituents such as myristicin, terpineol, apiole, cis-verbienol, and β- phellandrene are detected in seeds [38-39], while eugenol, trans-anethole, elemene, (E)-β-damascone were specified in leaves [41,42]. Terpenes as phytol, isophtyl and squalene are identified in leaves [36,41].

Lutein (xanthophyll), α-tocopherol carotenoids, β-carotene (with provitamin activity), α-carotene, violaxanthin, anteraxanthin, zeaxanthin, and neoxanthin are detected in leaf extract by high-performance liquid chromatography (HPLC) and open column chromatography [32,43,44].

Rocket known to contain significant concentrations of phenolics. Kaempferol as aglycone and glycosides is present in a higher percentage in eatable parts of rocket [6,31,45].

Kaempferol-3-glucoside (astragalin); kaempferol-3,4'-diglucoside; kaempferol 3-0-(2'-O-malonyl)-β-D-glucopyranoside)-4'-0-β-D-glucopyranoside; kaempferol 3, 4-di-O-glucopyranoside, 3-O-methyl 4-glucopyranoside, 4'-O-glucopyranoside; quercetin-3,4-diglucoside-3- (6-sinapoyl-glucoside); quercetin-3,3,4'-triglucoside; quercetin-3-(2-sinapoylglycoside)-3'-6-sinapoylglycoside)-4' glucoside; quercetin-3,3'-d-glucoside; rutin; quercetin-3,4'-d-glucoside-3-(6-cafeoyl-glycoside); isorhamnetin-3-glucoside; isorhamnetin-3,4'-diglucoside; rhamnocitrin 3-O-(2'-O-methylmalonyl)-β-D-glucogynoside)-4'-0-β-D-glucopyranoside; rhamnocitrin 3-O-glucopyranoside, 4'-0-glucopyranoside in rocket leaves juice and aqueous ethanolic extract of fresh leaves by ultrahigh performance liquid chromatography (UHPLC) and open column chromatography [52,43,44].

Rocket is a rich source of minerals and electrolyte. Different minerals had been identified in leaves which include phosphor (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) [27,61,62]. In leaves, Mg, Ca, Fe, and K are the prevalent minerals, while in seeds, the most abundant minerals are Ca, Na, P, and chromium (Cr) [6].

**PHARMACOLOGICAL ACTIVITIES OF E. SATIVA**

**Anticancer effect**

Anticancer effect of E. sativa is known in traditional medicine. Helicobacter pylori which are involved in the pathogenesis of ulcer have a high urease activity, and urease enzyme is essential to H. pylori metabolism and required for its colonization in gastric mucosa. E. sativa extract produces a marked reduction of urease activity and thus provides scientific confirmation for its use as an anticancer agent [63].

In experimentally induced gastric lesions, rocket extract has cytoprotective, anti-secretory, and anti- ulcer actions. The anti-ulcer activity may be mediated through an increase in prostaglandin, mucous synthesis, and/or antioxidant activity by inhibiting lipid peroxidation.

Phytochemicals reported in rocket leaves such as flavonoids, sterols, and/or triterpenes are well known for their antioxidant actions, to which anti-ulcer mechanisms may be attributed [64,65].

**Antioxidant effect**

Lipid autioxidation is initiated by a chain of lipophilic radicals. In vivo hydrogen peroxide (H2O2) is generated by several oxidase enzymes. H2O2, through hydroxyl free radical serves as a messenger molecule in the inflammatory mediators’ synthesis and activation; these mediators
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**E. sativa flower extract is a powerful antioxidant.** 1, 1-diphenyl-2-picrylhydrazyl free radical scavenging test and β-carotene bleaching test were used to estimate the antioxidant effect of flower extract [67].

The concentration of phenolics in leaves is 6 times more than that of rocket stems; kaempferol 3,4-di-O-glucoside, kaempferol 3-glucosyl quercetin 3-glucosyl, andisorhamnetin 3-glucosyl are the main phenolics in rocket leaves and proved to be a powerful antioxidant [68]. Seed extract contains significant levels of phenolics, these phenolics are considered as natural antioxidant through free radical scavenging or quenching effect. Furthermore, rocket seeds contain significant levels of glucosinolates, especially glucorucin, which demonstrates the antioxidant effects through phase II enzymes induction, by scavenging hydrogen peroxide and alkyl hydroperoxides gathered in cells and peripheral blood and by serving as a precursor of sulforaphane, a powerful inducer of detoxifying enzymes [69]. The activity of natural antioxidants is less than that of synthetic antioxidant [66].

**Antibacterial effect**

**E. sativa** seed extract has a potent antimicrobial activity, considering it as a promising antibacterial agent against resistant Gram-negative (G-ve) and Gram-positive (G+ve) bacteria [70] which confirm its use as a remedy in traditional medicine for the management of urinary, skin infections, fever, and diarrhea. The bioactive compounds, erucic acid, and isothiocyanates are responsible for antibacterial effect [7]. Isothiocyanates are intermediates formed when glucosinolates are released and hydrolyzed by the action of myrosinase. Allyl isothiocyanates have been shown to display antibacterial action against 

- Bacillus cereus IFO-13499, Pseudomonas aeruginosa IFO-13275, B. subtilis IFO-13722, Escherichia coli IFO-1649, and Staphylococcus aureus IFO-12732, Vibrio parahaemolyticus IFO-12711 E. coli O157:H7, H. pylori, and others [71]. It was found that extracts of E. sativa seeds had a remarkable antibacterial action against S. aureus and B. cereus [72]. Eruca seed oil also exerts antibacterial and antifungal effects [73].

**Effect on fertility**

Since Roman times, rocket was recognized as a powerful aphrodisiac remedy [74]. Ethanolic extract of E. sativa was reported to have an androgenic action or induce testicular steroids production which stimulates the preputial gland, as well it enhances spermatogenesis in the male mice testis [75]. A considerable rise in testosterone hormone level and sperm activity was attributable to the extract of rocket leaves; furthermore, a significant reduction in sperm death and abnormalities was observed. The existence of saponins and alkaloids in rocket extract produce a significant enhancement in sperm activity. On comparison to the control group, histological sections of seminiferous tubules showed a significant increase in diameter of these tubules, spermatids, and Leyding cells and reduction in interstitial space was observed after five weeks of using with E. sativa extract. This increment might be attributed to the ability of rocket extract to activate testes growth and enhancement of spermatogenesis, maturation, and differentiation as compared with the control group [76]. Rocket seed oil showed a protective effect against nicotine-induced testicular damage by reversing (almost entirely) all morphometric and histological modifications in testis caused by nicotine [77].

Both Eruca leaves and seeds have aphrodisiac effect. In seeds, the aphrodisiac effect may be attributed to desulfglucoisatinolates, erucic acid, and an essential oil that is rich in isothiocyanates or to a combination of these phytochemicals [78].

Mona et al. in their study revealed that small doses of seeds oil stimulate spermatogenesis, while large doses suppress spermatogenesis possibly due to erucic acid high content [79].

**Hepatoprotective effect**

Ethanolic and aqueous rocket leaf extracts demonstrate hepatoprotective effect against carbon tetrachloride, phosphoric acid, and paracetamol-induced liver toxicity [11,20,25]. The liver toxicity is due to free radicals that have the ability either for proteins binding or abstracting a hydrogen atom from unsaturated molecules of lipid, and hence, accelerating or fastening lipid peroxidation and toxic effect. El-Nattat and ElKady said that the activities of alamine aminotransferase and aspartate aminotransferase are promoted due to rocket administration in male rabbits, and this probably attributed to the high sulfur content in rocket that expels body wastes. E. sativa leaves and seeds significantly restore non-protein sulfhydryl level in liver tissue and glucoerucin (the major glucosinolate in rocket) which has been involved in tissue damage and pathogenesis of various diseases such as diabetes [66].

**Hyperlipidemic effect**

The major cause of atherosclerosis which is highly correlated to ischemic heart disease is hypercholesterolemia and hypertriglycerideremia [81]. E. sativa leaf extract possesses antihyperlipidemic and antihypercholesterolemic effects [82]. The antihyperlipidemic action of rocket leaf extract perhaps due to Vitamin C activation of the 7 alpha-hydroxylase enzyme. E. sativa leaves contain Vitamin C, which promotes plasma cholesterol conversion into bile acid, as a result subsequent decrease in serum cholesterol levels, additionally the capacity of the Vitamin C to prevent the oxidation of high-density lipoprotein [23]. The rocket oil hypocholesterolemic effect perhaps due to the phytosterols; β-sitosterol, campasterol and beta-amyrine. (these sterols decrease cholesterol concentration by preventing its absorption and inactivation of the hepatic cholesterol esterase) or due to high ratio of unsaturated fatty acids which decrease lipoproteins.
production. Phytosterols reduced the dietary and biliary cholesteral conjugation into micelles, and this depresses cholesteral absorption. Synthesis of cholesteral and low-density lipoprotein (LDL) receptors activity is increased, which eventually leads to reduced serum LDL-cholesteral concentration. The rocket oil hypocholesterolemic effect is better than that of olive oil [82,83]. Hence, rocket oil decreases the total cholesteral, total lipid, and LDL concentration and can be considered as worthy source for omega fatty acids and might be consumed as a healthy oil to minimize saturated oil consumption. Saturated oils and fats are the reasons for the development of several chronic illnesses [84].

**Antihypertensive effect**

Rocket had been utilized as a remedy in traditional medicine for managing the cardiovascular complaints, particularly hypertension [85-87]. Oral and intravenous administration methanolic extract of rocket aerial parts and its fractions (especially aqueous fraction) demonstrates hypotensive effect in normotensive and hypertensive rats (hypertension is induced by high salt diet). The antihypertensive effect is the net result of vasodilatory and cardioinotic effects. Vasodilatory mediators, as nitric oxide and certain muscarinic receptors existing on vascular endothelial cells, are implicated in vasodilatation. Activation of these receptors ultimately leads to nitric oxide production. Rocket extract also has a direct influence on vascular smooth muscle in rat. Crude extract and, especially, ethyl acetate fraction are loaded with flavonoids and phenols; previous studies revealed that the flavonoids and phenols have anticholinesterase and cardio protective effects and may be implicated in hypotensive effect. Erucin (also major component of rocket) is produced from sulforaphane metabolism. Sulforaphane is known with potential hypotensive effect, so the antihypertensive effect is possibly due to quercetin, erucin, and other rocket constituents [88].

**Antidiabetic effect**

Rocket seeds and leaves ameliorate hyperglycemia and produce antidiabetic effect [89-91]. *E. sativa* seed oil has powerful antihyperglycemic and antihyperlipidemic actions in streptozotocin (STZ)-induced diabetic rats. High glucose concentration yields reactive oxygen species (ROS) due to autodization, metabolism of glucose, and the development of advanced glycosylation end products. ROS activates lipid peroxidation that causes devastation and injury to the cell membrane; lipid peroxidation is one of the distinctive features of chronic diabetes.

The protecive effects of rocket seeds oil against hyperglycemia and hyperlipidemia probably as a result of their ability to modulate the pancreatic islets architecture, antioxidant activity (through free radical scavenging activity), increasing (glutathione and superoxide dismutase concentration) and insulin secretory response [92,93].

*E. sativa* extract shows suppressing effect on carbohydrate metabolism through inhibition of carbohydrate-hydroplyzing enzymes, α-amylase, α-glucosidase, and β-galactosidase in dose-dependent manner. Aqueous extract exhibited less inhibitory effect than ethanolic extract on carbohydrate metabolism [91].

Oral administration of rocket leaves extract in STZ-induced diabetic rats greatly retrieves the abnormal parameters in experimental animals. Hence, *E. sativa* may be valuable for patients who suffer from diabetes [94].

**Antifungal effect**

Rocket leaf oil that extracted by steam distillation has significant antifungal effect assessed by well-diffusion method. The extracted oil has a high rate of inhibition (60-67%) against Dreschlera halodes, Cola clavata, Rhizopus oryzae, and Aspergillus nidulans. While the oil moderately suppress *Alternaria kiliense* (4%), *Alternaria alternata* (38%) and exhibited minimum inhibition against *F. oxysporum* with [13%] [14]. Powdered seeds of *E. sativa* demonstrate antifungal effect. Crude aqueous seeds exhibited strong powerful antifungal effect against the fungus *Spadicoides stoveri* and *Paeclionyces variotii* while insignificant inhibition against other fungal strains [95].

**Anti-inflammatory and antiademia effect**

Rocket seeds are used by traditional herbalists for the management of rheumatoid arthritis. Abodola et al. designed a study to assess the anti-inflammatory effect of *Eruca* seeds, and his study revealed that ethanolic seed extract demonstrates a dose-dependent sustained anti-edema action superior to indomethacin. The anti-inflammatory effect of seeds possibly mediated through flavonoids as quercetin and isorhamnetin, also to 4-methylthiobutyl isothiocyanate (main isothiocyanates in seeds). 4-methylthiobutyl isothiocyanate inhibits the expression of pro-inflammatory genes, tumor necrosis factor-alpha, and some other interleukins (ILs). Non-steroidal anti-inflammatory drugs are known for their deleterious effect on gastric mucosa, while *E. sativa* extract has gastroprotective effect. Large doses of rocket may cause anaphylaxis and immunosuppression [96].

**Nephroprotective effect**

Rocket is generally used in traditional medicine as a remedy for renal disease. Elgazar and his colleague proved that *E. sativa* induced diuresis and has nephroprotective effect against gentaminc-induced nephrotoxicity in rats [97,98].

The rocket alloscholic seed extract has nephroprotective action in mercuric chloride (HgCl₂)-induced nephrotoxicity. This protective effect due to the ability of seed extracts of *E. sativa* for rising or maintaining the antioxidant molecules and antioxidant enzymes levels in the kidney and through the protective effect to kidney, thereby protect the tissues against oxidative damage. Flavonoids and glucoerucin present in rocket seeds extract may be involved in nephroprotective activity [99].

Hussien proved in his study that the aqueous extract of *E. sativa* successfully prevents the occurrence of nephrocalcinosis in rabbits through suppression calcium oxalate crystal formation and deposition in renal tissues. Prevention of nephrocalcinosis of rocket is due to its diuretic effect and alkalization of urine (calcium oxalate crystals deposing is enhanced in acidic urine). Furthermore, *E. sativa* has a large amount of magnesium, and thus, it may lessen free oxalate in intestine and urine, reducing its availability for binding to Ca ion in renal tubules, and thus, calcium oxalate crystal formation is suppressed [100-102].

**Antiplatelet effect**

Platelets activation has a role player in the development of acute thrombus and cardiovascular diseases. Hydroalcoholic extract of rocket leaves exhibited antiplatelet effect (both in vivo and in vitro); as it prevents thrombus formation without significant risk of bleeding. *E. sativa* extract restrains thrombocanx B2, tissue growth factor (1β), and IL-1β which are platelet inflammatory mediators, and these mediators participate in the development of atherosclerotic lesion and arterial thrombogenesis. Human platelet CCL5 levels which are induced by adenosine diphosphate also inhibited by *E. sativa* extract but to lesser extent. These effects ultimately prevent thrombus development. *E. sativa* Mill antiplatelet activity could be explained by the existence of kaempferol, quercetin, and isorhamnetin. Kaempferol derivatives are the major phenolics in rocket leaves [103].

**Other effects**

A mixture of milled seeds of *E. sativa* and cream was applied on the face for its anticaene effect [104]. Lotion of *E. sativa* promotes hair regrowth and reverse greyey sculp [105]. Orally administered mixture of seeds oil and sugar is used for the treatment of dysentery [106].

**STUDIES INVOLVE DEVELOPMENT OF PHARMACEUTICAL PREPARATION CONTAINING *E. SATIVA* EXTRACT**

Shatalebi et al. studied the development of an oil/water (o/w) hair wax formulates for hair growth containing ethanolic extract *E. sativa* seed oil, with the aid of thickening agents in different concentrations.
The resultant formulations were evaluated and compared to brand marketed product. Best results were observed with formula containing 10% ethanolic extract of propolis and 10% E. sativa seed oil. This formula increased the hair length, the newly grown hairs weight, and improved percentage phase of hair follicles [107].

Sanad et al. formulated and evaluated enriched garlic and Eruca oils stable cream with antibacterial activity. Different formulations were prepared using different concentrations of two surface active agents. Cream prepared with 2% surfactant mixture showed well-designed formulation and best antimicrobial activity [108].

Taha et al. formulated a new herbal antifungal hair cream containing Eruca and garlic oils, active on pathogenic fungi (Malassezia farfur, Microsporum canis, Bodin, and Trichophyton mentagrophytes) using different ratios of non-ionic surfactant. Highest permeation rate of allin in the presence of Eruca oil which is necessary for antifungal activity was obtained with formula of 4% concentration of Span and Brij [109].

CONCLUSION

Plants and herbal extracts constitute a vital position in modern medicine; E. sativa is an important nutraceutical that has diverse phytochemicals. Although the plant was excessively studied and many compounds have been isolated, further studies are required to support the traditional uses of plant. Scientific research should be employed to isolate, elucidate, and specify the chemical structure of each compound responsible for specific pharmacological action. In addition, more pharmaceutical studies should be employed to formulate more dosage forms containing the active constituents of E. sativa due to broad pharmacological activity of them.

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AUTHORS' CONTRIBUTION

We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. Both Dr. Noor S Jaafar and Dr. Iman S Jaafar assembled and studied the data. Dr. Iman S Jaafar proof read the whole manuscript and recommended the required changes and Dr. Noor S Jaafar assist in designing manuscript.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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