Chenopodium album

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Bathua (*Chenopodium album*) is a rich source of extensive-ranging nutrients, including bio-active carbohydrates, flavonoids and phenolics, minerals, and vitamins that translate to countless health benefits such as anticancer, antidiabetic, anti-inflammatory, antimicrobial, and antioxidant activity. Ascaridole, an important phytoconstituent present in aerial parts of the plant, contributes to its anthelmintic property.

Keywords: Chenopodium album ; food applications ; impact of the processing ; ethnobotanical use

1. Characteristics and Cultivation of *C. album*

1.1. Botanical Description and Vernacular Names

C. album is a pale green, erect, and strong-smelling polymorphous annual herb of a height of up to 3.5 m, growing 3600 m above sea level. The word “Chenopodium” is derived from two Greek words, viz., “khen” (goose) and “pous” (foot), describing the goosefoot shape of most of the species belonging to the genus. The taxonomic features of the plant include kingdom, phylum, subphylum, class, order, and family, viz., Plantae, Spermatophyta, Angiospermae, Dicotyledonae, Caryophyllales, and Amaranthaceae. The leaves are simple and alternate, oval to obovate or lanceolate shaped with length and width of 1.5–8 cm and 3 cm, respectively, and are attached to the petiole. Decussate leaves are grown first, followed by alternating with long, oval onboard teethed alternate leaves. The stem is cylindrical to angular, erect, grooved, usually branched, and often reddish [1][2]. Dense inflorescence formed by the aggregation of flowers are attached to the leaf axils at the terminus of stems. Small flowers possess radial symmetry and grow on dense branched inflorescence of 10–40 cm in length. The seeds are black, smooth and shiny, horizontally flattened, and lenticular with a diameter of 0.7–1.5 mm. The cotyledons are fleshy, elliptic, elongated, 10–15 mm long and 2–3 mm wide, and shortly petiolate [3][4].

The common English names of *C. album* include “Melde”, “Lamb’s quarters”, Fat-hen”, “Goosefoot”, “Misbredie”, “Withondebossie”, “Umbikicane”, “Bloubossie”, “Wild spinach”, “Misbredie”, “Varkbossie” and “Pigweed”. The vernacular names used in different parts of India are “Chandan betu” (Bengali), “Pappukura” (Telgu), “Bathua Sag” (Hindi), “Katu ayamoddakam” (Malayalam), “Parupukkirai” (Tamil), “Bathava” (Gujrati) and “Bathu” [5]. The plant names according to Ayurveda, Siddha, Folk and Unani systems of medicine are “Vaastuuka”, “Paruppukeerai”, “Chilli-shaak”, and “Baathu”, respectively [6].

1.2. Cultivation Information

C. album is a widely distributed weed plant, mainly in Asia, Africa, Europe, and North America; it grows in nitrogen-rich soils. Around 21 species of the plant are found in India, particularly in Rajasthan, Kullu valley, and Shimla. The most likely companions of the weed plant are corn, potatoes, and cucurbits. The plant can be traditionally grown in nitrogen-rich soils using the hydroponic method [7][8]. The soil required for the growth of the plant should be moderately fertile; a pH of 4.5 to 8.3 is tolerable. The germination potential of freshly harvested seeds remains around 35%; however, low-temperature (0 to 5 °C) treatments have been found to increase the germinability as prolonged soaking over 20 days do. The percentage of germination is maximum for seeds lying just below the soil surface. The difference in germination optima at different temperatures reflects the different behavior of plants at varying places [1]. Interestingly, the plant is frost tolerant. The longer exposure of the plant to sunlight results in larger and more vigorous plants which discloses the reason for sparse distribution around the equator and extensive distribution in temperate regions [9].

2. Ethnobotanical and Ethnomedicinal Use of *C. album*

The traditional ayurvedic book *Ashtang Hridaya* emphasizes the importance of meshed dishes prepared by cooking greens of *C. album*. The ancient “Vedas” written by sages also puts the plant into the spotlight. The “Rig Veda” and “Atharva Veda” highlight the beneficial effects of *C. album* in the treatment of piles, clearing worms, and as a laxative. The

knowledge compiled from these Vedas and edited by “Agnivesha” and “Charaka”, respectively, has led to a legendary compilation, *Charaka Samhita*, which, along with *Sushruta Samhita*, is still used by the practitioners of the traditional system of medicine. Both these books underscore the importance of *C. album* in improving digestive power, memory, appetite, and body strength [10][11][12]. In addition, it has been said to have purgative action and help to relieve constipation [13].

Although manual cultivation of the herbaceous pot plant, commonly known as *bathua,* is not widely practiced in India, its growth can be easily detected in the corners of early grain fields in the country. Since long ago, the plant has been employed in the diet as well as for the management of several diseases; the leaf extract is still used in the Ladakh region (India) for controlling painful urination [14]. Ethnomedicinal surveys revealed the utilization of decoctions prepared from different plant parts as herbal remedies for several diseases. Whole-plant decoction has been employed for anthelmintic purposes and the management of jaundice and other liver diseases in various parts of Pakistan (PAK), including Hattar, Gulla Khel, and Makerwal [15][16]. Additionally, the decoction prepared from aerial parts is known to be utilized to treat stomach diseases and gastrointestinal disorders in Gilgit-Baltistan, PAK [17]. The use of the plant for treating indigestion and constipation is also practiced in the Parbati Valley of Kullu, and Sikandra Hill Range of Mandi, Himachal Pradesh [18][19]. In addition, the anthelmintic property has also been reported in myrrh (*Commiphora molmol*), tulsi (*Ocimum sanctum*), papaya (*Carica papaya*), and ginkgo (*Ginkgo biloba*) [20].

Moreover, the treatment of kidney stones and urinary tract complications with cooked *C. album* leaves and/or herbal tea made from them is considered to be the appropriate treatment option in the folk medicine of Rajasthan, Toba Tek Singh, and Azad Jammu and Kashmir [21][22][23]. Additionally, people of the Shekhavati region of Rajasthan make use of cooked *C. album* leaves for the treatment of colic and other urinary system issues [24]. Furthermore, the tribal use of fresh leaves and flowers for vegetables and dried plant powder for diuretic purposes has been reported in Chonthra Karak (Pakistan), and Garhwal (India) [25].

Interestingly, the plant is reported to possess sexual health-promoting properties [26]. The oral consumption of whole-plant powder for the treatment of sexually related problems is practiced in Gujranwala and Lower Kurram [27][28]. In the trans-Himalayan region of India, half a spoon of whole-plant powder is used for treating headaches and seminal weakness [29]. The use of plant seeds and leaves for the treatment of unconsciousness and removal of thirst has also been reported in Mirpur (Pakistan) [30]. Interestingly, the use of amla (*Emblica officinalis*), black pepper (*Piper nigrum*), wild mint (*Mentha arvensis*), tamarind (*Tamarindus indica*), and allium (Allium odorosum) has also been reported for the treatment of kidney stones by Muslim herbalists [31].

The ethnobotanical uses of cooked plant parts (leaves and stems) further extend to the treatment of flu, gall stones, and tuberculosis. The traditional uses of the plant also include the treatment of sunstroke, sunburn, and swollen feet [32][33]. The herbal drink (fresh infusion) prepared from the whole plant is also used to treat intestinal ulceration in traditional communities of Pakistan [34]. Besides the other uses of the plant, the village peoples of Thoppampatti, Tamilnadu utilize the whole plant for anti-scorbutic uses [35]. Furthermore, the plant is also used as a blood purifier by rural communities of the Arid regions of Punjab, Pakistan [36]. The plant is used for treating skin-related problems in Dehradun, Uttarakhand [37]. The use of the whole plant in the treatment of enlarged spleen and plant roots for the treatment of rheumatism and snake poison in Islamabad is also being practiced [38]. Additionally, the erythropoiesis-stimulating activity of the *bathua* plant is ethnobotanically employed for the treatment of anemia in the Kumaun Himalayan region [39].

3. Nutritional and Phytochemical Profile of *C. album*

3.1. Vitamins and Minerals

The plant is a rich source of vital minerals and vitamins for the body in which retinol, ascorbic acid, B-complex, calcium, and potassium are predominant. The mineral content present in the leaves of *C. album* is much comparably higher than in other consumed vegetables such as beet, mustard leaves and spinach [40]. The concentration of minerals varies among raw and cooked vegetables. The average content of minerals/100 g of raw lamb’s quarters is known to be as follows: calcium—309 mg, magnesium—34 mg, potassium—452 mg, iron—1.2 mg, phosphorous—72 mg, sodium—43 mg, and other elements including selenium, copper, manganese, and zinc in small (less than 1 mg) quantities. Zinc and iron present in leafy vegetables are essential for a healthy immune system and combating anemias. In addition, the plant is a good reserve of retinol and ascorbic acid. The average vitamin content present/100 g of the raw plant is noted to be the following: retinoic acid—11,600 IU, ascorbic acid—80 mg, niacin—1.2 mg, and a trace amount of thiamin, riboflavin, pantothenic acid, pyridoxal, and folate (30 µg/100 g) [41]. One study utilized the thiocyanate method to determine in vitro bioavailability of iron from fresh and dehydrated leaves of Bathua and food made from it [42]. The in vitro bioavailability of

iron from paratha and laddoo made from leaves was found to be 2.16 mg/100 g and 2.78 mg/100 g. In addition, the calcium present in raw as well as cooked *C. album* leaves has been reported to be 32 to 33% bioavailable [43].

3.2. Carbohydrates

Polysaccharides are formed by the linking of several monosaccharide units attached by glycosidic linkages. Further, the biological functions of the resulting polymers are influenced by the degree of polymerization, types of monosaccharide units attached, and the glycosidic linkages. The total carbohydrate content in the raw and cooked lamb quarters is reported to be 7.3 g and 5 g/100 g, respectively [41]. Fructose, glucose, lactose, maltose, and sucrose have been reported in young shoots and mature plants [44]. Dietary fiber is part of a plant-derived food product that is not completely digestible in the human intestines. The consumption of a fiber-rich diet is associated with a reduced risk of cardiovascular diseases. Total dietary fibers represent about 4 g of total carbohydrates in 100 g of raw vegetables. However, some studies have reported a higher content of dietary fibers in young shoots and mature plant material [40].

3.3. Protein and Amino Acids

The nutritional quality of a plant in terms of protein content is governed by the presence and proportion of essential amino acids in the plant/food product. Essential amino acids are not biosynthesized by the human body and are vital for bodily functions. High protein content and a balanced spectrum of amino acids are some of the reasons behind the consumption of *C. album*. The green leafy part and seeds represent the highly valuable parts for the protein content, particularly higher in lysine due to its synthesis and gathering in a soluble and protein form. The average protein content in the raw lamb's quarters is known to be 4.2 g/100 g of material [41]. However, some studies have reported even higher protein content, such as 203 g/kg and 32.2 g/100 g in vegetation matter [44][45]. The content of isoleucine, leucine, phenylalanine, threonine, and valine in the green matter protein is reported to be even higher than that in seeds [5]. Among essential amino acids, arginine (11.29 g/kg), leucine (13.44 g/kg), lysine (10.11 g/kg), and phenylalanine (9.26 g/kg) are mainly present in the green matter, while those predominating in seeds are arginine (17.18 g/kg), leucine (7.58 g/kg) and lysine (8.07 g/kg) [45].

3.4. Fatty Acids

Quite a low yield of oils but rich amounts of essential oils are found in the leaves of wild edible plants. Essential fatty acids belonging to the ω^3 series were found in the *C. album*. These fatty acids are known to play a valuable role in modulating human metabolism as well as prevent against coronary heart diseases [46][47]. According to the U.S. Department of Agriculture, the total lipid content in the raw lamb's quarters is reported to be 0.8 g/100 g, with saturated fatty acids (0.059 g), monounsaturated fatty acids (1.05 g), and polyunsaturated fatty acids (0.351 g) [41]. The predominant fatty acids are 18:3ω^3, 18:2ω^6, and 16:0. However, unusual fatty acids such as eicosapentaenoic acid and docosahexaenoic acid are absent in the leaves [47]. The polyunsaturated fatty acid composition of a plant may provide beneficial effects towards prevention of diseases such as osteoarthritis and autoimmune disorders. Comparatively, the fatty acid content in leaves is higher compared to that of roots. Along with the salt tolerance of *C. album*, the total composition of fatty acids in the plant parts was reported to remain unaffected under salt stress conditions [48].

3.5. Phytochemicals

Apart from the appreciable composition of carbohydrates, protein, and fats, other phytochemicals belonging to the class of alkaloids, saponins, terpenoids, flavonoids, and phenolic compounds make *C. album* a versatile revitalizing source. Phenolic compounds in the plant are responsible for several biological activities, including anticancer, antihyperglycemic, anti-inflammatory, antimicrobial, and lowering of adipogenesis [6][49][50]. The high content of crude alkaloids is responsible for the spasmolytic and anesthetic activity. Additionally, the leaves are reported to contain carotenoids which possess provitamin-A activity and hence promise antioxidant activity [51].

The essential oil obtained by hydro-distillation was found to be composed of higher hydrocarbons, oxygenated and bicyclic mono-, di- and sesquiterpenoids, and fatty acids [49]. Volatile oil obtained from the plant was found to be composed of (*E*)-ascaridole, carvacrol, (*Z*)-carvyl acetate, *p*-cimen-80-ol, (*E*)-piperitol acetate, benzyl alcohol, *p*-mentha-1,3,8,-triene, *p*-cymene, α-terpinene, *p*-cresol, and piperitone [52]. These components were reported to account for 90.4% of total volatile oil. Phytol was identified to be the most oxygenated diterpene in the oil. In addition, some studies have reported the α-pinene as the most abundant and pinane-2-ol to be the most oxygenated monoterpene component of the essential oil [53].

Furthermore, ester compounds of hexadecenoic acid, 9-Octadecenoic acid and 9,12-Octadecadienoic acid owing to valuable activities such as antibacterial, antifungal, antioxidant, antiviral, anti-inflammatory, and nematocidal activity have been reported to be present in the roots of the plant [54][55]. Volatile organic compounds synthesized by microorganisms have shown significant plant growth-promoting activity by regulating photosynthesis and other vital functions. Interestingly, the volatile organic compound cryptomeridiol obtained from seeds shows significant plant growth-promoting activity [6][56][57]. The methanolic extract of roots has revealed the presence of a novel compound, chenoalbicin, with an alkaloid moiety attached to a cinnamic acid amide. The compound was reported to have allelopathic effects [58][59]. The chemical structures of phytochemicals identified in the different plant extracts and oil are given in **Figure 1**. Phytic acid, an antinutritional compound present in the leaves of the plant, acts as a major phosphorous storage compound. The phytochemical impairs the absorption of important mineral ions such as calcium, iron, and zinc, which are present in a co-administered diet [60].

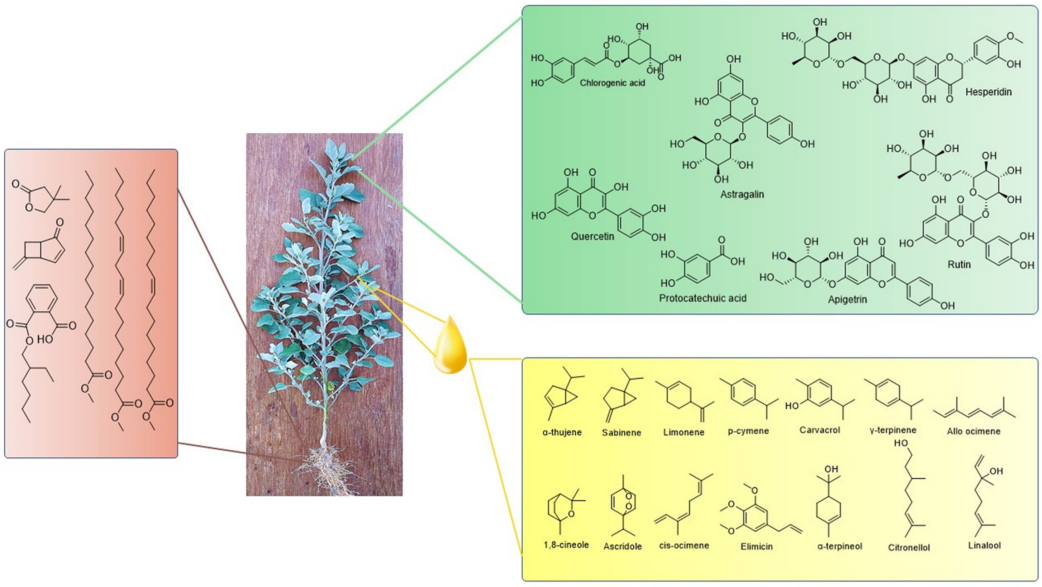

Figure 1. Biologically active phytoconstituents present in different parts of *C. album*.

4. Functional Activities of *C. album*

4.1. Antimicrobial Activities

Antimicrobial activity of different molecules is executed by several modes, including disruption/inhibition of cell wall synthesis and protein synthesis, and by binding to different functional units and inhibiting their functions. Interestingly, *C. album* has been reported for its valuable activity against bacteria, fungi, and nematodes. The antimicrobial activity of the *C. album* is discussed below.

4.1.1. Antibacterial Activity

The antibacterial activity of oil obtained by hydro-distillation of *C. album* leaves against Gram-positive and Gram-negative strains has been investigated [49]. Agar well diffusion, agar disc diffusion and microdilution assays revealed significant antibacterial activity against MDR bacterial strains with inhibition zones ranging from 7.0 ± 0.0 mm to 16.0 ± 6.6 mm (in the disc diffusion method) and from 7.0 ± 0.6 mm to 15.0 ± 1.0 mm (in the well diffusion method). Among the tested strains, oil was found to be most effective against *Escherichia coli* (MIC 1.25 mg/mL and MBC 2.5 mg/mL), *Shigella dysenteriae* (MIC 0.62 mg/mL and MBC 1.25 mg/mL), *Shigella sonnei* (MIC 1.25 mg/mL and MBC 2.5 mg/mL), *Salmonella typhimurium* (MIC 0.31 mg/mL and MBC 0.62 mg/mL), and *Staphylococcus aureus* (MIC 1.25 mg/mL and MBC 2.5 mg/mL).

In another study, the water extract of *C. album* exhibited significant anti-bacterial action against Gram-positive (*Bacillus cereus* MIC 0.5 mg/mL, *Staphylococcus epidermidis* MIC 0.5 mg/mL, *Staphylococcus aureus* MIC 1.0 mg/mL, *Micrococcus cristinae* MIC 0.5 mg/mL, and *Streptococcus pyogens* MIC 0.5 mg/mL) and Gram-negative (*E. coli* MIC 1.0 mg/mL, *Salmonella pooni* MIC 1.0 mg/mL, and *Serratia marcescens* MIC 1.0 mg/mL) strains [61].

Additionally, Korcan and co-authors investigated the antibacterial activity of methanolic extract and reported maximum activity against *Bacillus subtilis* (13 mm zone of inhibition at 100 µg/mL), and the activity was found to be increased with increasing concentration of extract [62]. Lone et al. reported the maximum inhibiting activity of the methanolic extract

against *S. aureus* with an inhibition zone of 28 ± 0.14 mm and a mild effect against *E. coli* among the tested organisms [63]. Interestingly, Umar and colleagues employed the leaf extract as a reducing agent in the development of reduced graphene oxide nanoparticles displaying antimicrobial activities. The significant antibacterial activity of the plant warrants its potential as a potent antibacterial agent [64]. However, further research is needed to isolate and identify the specific molecules responsible for the action.

4.1.2. Antifungal Activity

The antifungal potential of *C. album* against various pathogenic phyto-fungi has attracted scientific interest in recent years. Alkooranee et al. investigated the antifungal potential of *C. album* roots and leaves against phytopathogenic fungi, including *Alternaria alternate*, *Fusarium solani*, *Pythium aphanidermatum*, *Rhizoctonia solani*, and *Sclerotinia sclerotium*. The water extract of leaves and roots was reported to have a significant mycelial growth reduction effect [65]. Furthermore, Sherazi [66] explored the antifungal activity of *C. album* for the management of *Ascochyta rabiei*, which are implicated in chickpea blight. Among different fractions of methanolic extract of *C. album* leaves, the n-hexane fraction exhibited the highest antifungal potential. In addition to the above, Javid and Rauf utilized the methanolic leaf extract for controlling the basal rot disease (caused by *Fusarium oxysporum*) of onion [67]. The chloroform fraction of methanolic extract exhibited the maximum antifungal activity by reducing 96–100% of fungal biomass. Inflorescence extract possesses the highest antifungal activity against *F. oxysporum*, and a possible management of the problem was achieved by employing methanolic inflorescence extract as a natural fungicide [68]. The antifungal potential of plant roots against *Sclerotium rolfsii*, soil-borne phytopathogenic fungi has been investigated. The methanolic extract of roots was reported to significantly reduce fungal biomass. Furthermore, the abundant compound in the extract, as identified by GC-MS, was found to be mono(2-ethylhexyl)ester of 1,2-benzenedicarboxylic acid [54].

4.2. Anthelmintic Activity

The current epidemiology, unavailability of vaccines for intestinal infections, and the resistance to chemotherapy have made it compelling to discover and develop novel anthelmintic drugs. Medicinal plants, which are continuously the source of novel medicinally useful molecules, have attracted scientific interest for the purpose. Further, Peachey et al. [69] investigated the anthelmintic potential of *C. album* against cyathostomins, a most important gastrointestinal nematode infecting equids. Plant extracts were prepared by drying, milling, macerating with methanol, and vacuum evaporation. Larval migration inhibition test and egg hatch test revealed the significant anthelmintic activity of *C. album*, with the lowest value of EC_{50} at 2.3 mg/mL. Lone et al. [63] reported dose- and time-dependent anthelmintic activity against *Haemonchus contortus*. Worm mobility inhibition assay and fecal egg count reduction assays were used to determine in vitro and in vivo anthelmintic activity. Methanolic extract possessed more significant anthelmintic activity than aqueous extract. In contrast, it has been reported that the aqueous extract is better in terms of anti-parasitic activity against *H. contortus* [70]. The anthelmintic potential of *C. album* extracts against adult *Eisenia fetida*, an Indian earthworm, has been investigated [71]. Among all extracts, ethyl acetate was reported to exhibit highly significant anthelmintic activity at a 10 mg/mL concentration by causing paralysis and fatality of the earthworms, with paralysis and death time reported to be 10.08 ± 1.11 and 65.28 ± 2.09, respectively. Furthermore, the reversible paralysis of body wall muscle was caused due to the GABA-mimetic action of the extract. Whole-plant extract of *C. album* was also reported to possess ovicidal efficacy against GI nematodes in goats with ED_{50} and ED_{90} values of methanolic, ethylacetate and chloroform extracts at 3.86 and 7.14, 2.73 and 8.31, 4.41 and 20.11 mg/mL, respectively [72].

4.3. Hepatoprotective Activity

Infections, increased alcohol consumption, anemia, malnutrition, and availability of hepatotoxic drugs over the counter have been implicated as the most common reasons behind liver diseases [73]. The conventionally used drugs for the treatment may lead to serious adverse effects. The use of natural remedies prepared from medicinal plants could be promising. In such context, the hepatoprotective potential of *C. album* has been intensively explored by researchers in recent years. In vitro hepatoprotective potential of aerial parts of *C. album* in Hep G2 cells was reported; compounds isolated from extracts including nemanolone D, nemanolone E, and substituted 5,7-dimethoxy-cyclohepta-furan-6-one derivatives showed notable activity to lower AST and ALT levels in Hep G2 cells treated with H_2O_2 and hepatoprotective potential against paracetamol-induced liver damage [74][75]. Moving further, biochemical marker analysis and histopathological studies revealed the hepatoprotective action of aqueous and alcoholic extract as evinced by restored levels of alkaline phosphatase, bilirubin content, and serum transaminases, and reversal of liver damage induced by the toxin. Moreover, the methanolic extract of *C. album* has been reported to protect the liver against ethanol-induced liver damage [76]. The liver protection potential of the plant is extended to CCl4-induced liver damage. The extracts of powdered plant material were found to alleviate the CCl4-induced elevated levels of ALT, AST, bilirubin, and total cholesterol. The methanolic extract was found to exhibit the significant hepatoprotective activity the most [77][78][79].

4.4. Antioxidant Activity

The general in-built antioxidant mechanism of the human body, which ought to equipoise between reactive oxygen species (ROS) production and antioxidant activity, is often disturbed in long lifetime, increased oxygen consumption, and production of reactive nitrogen species. The oxidative stress generated in this was leads to the pathogenic development of neurodegenerative diseases, diabetes, cancer, vascular diseases, kidney diseases, pulmonary diseases, and aging. Plant polyphenols, including flavonoids and non-flavonoids, possess significant antioxidant activity to combat radical-initiated oxidative damage [80][81][82][83][84][85][86].

The mechanism of antioxidation involves the scavenging of free radicals and/or inhibition of the production of reactive oxygen species [87][88]. *C. album*, due to the presence of a considerable amount of polyphenols, exhibits strong antioxidant activity. The antioxidant activity of aqueous and alcoholic extract of *C. album* was assessed by DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) assay, superoxide anion radical scavenging activity-riboflavin photo-oxidation method, hydroxyl-scavenging activity-deoxyribose assay, and lipid peroxidation method. DPPH assay revealed the aqueous extract to possess the highest percentage (96%) of free radical inhibition while the riboflavin photo-oxidation method and hydroxyl scavenging method evinced methanolic extract to exhibit the highest and most significant antioxidant activity [63]. Moreover, superior DPPH free radical scavenging activity has also been reported [89]. Researchers employed NBT (nitroblue tetrazolium reduction test) and ABTS (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) radical scavenging activity methods in extra to assess the antioxidant activity of *C. album* seed extracts. The superior DPPH free radical scavenging of aqueous extracts may occur due to the presence of more hydrogen donors to scavenge the free radical [63]. The results of the Ferric reducing antioxidant power (FRAP) assay, in addition to the ABTS assay, have corroborated the antioxidant activity of *C. album* [3].

4.5. Anticancer Activity

The continuous hunt for novel anticancer drugs and previously discovered anticancer molecules from plants has led to increased scientific attention towards plant extracts and the phytochemicals present in them. Phytochemicals, including taxanes, Catharanthus alkaloids, geniposide and derivatives, and other compounds such as artesunate, colchicine, and roscovitine possess the significant anticancer potential to be used in the management of cancer [90].

The anticancer potential of commonly consumed plant *C. album* has been assiduously scrutinized by researchers across the globe. Rana et al. investigated the in vivo anticancer potential of *C. album* leaves against Ehlrich ascites carcinoma (EHC) cells in Swiss albino mice. Results have revealed the statistically significant cell growth inhibition of 30.60% and 41.80% at the concentration of 200 mg/kg and 400 mg/kg of *C. album* extract, respectively. Moreover, the treatment was found to reinstate all the biochemical parameters, including hemoglobin content, red blood cell (RBC), and white blood cell (WBC) count in the mice. The inhibition of cell growth, a decrease in tumor weight, increase in mean survival time, and induction of apoptosis were all concluded to be contributors to the anticancer effect. Plant-sourced lectins are known to instigate apoptosis and autophagy of cancer cells [91]. In a study, lectin (175 µg/mL) isolated from *C. album* seeds showed strong anti-cancerous potential in hepatoma HepG2 cells as evinced by significantly decreased transcription levels of AFP and GPC3 levels by 90% and 89%, respectively [92].

Interestingly, Umar et al., 2020, formulated the reduced graphene oxide nanoparticles using an extract of *C. album* as a reducing agent. The anticancer activity against MCF-7 cells of the developed nanoparticles suggested a new approach for the treatment of breast cancer [64]. Moreover, tropolone-based compounds, which included two new tropolones and three known tropolone derivatives (lactarotropone, 2,9-epoxylactarotropone, and 6-lactaradien-5-oic acid γ-lactone) obtained from the aerial parts of the plant have been reported to exhibit notable in vitro anticancer activity against human tumor cell lines including HGC-27 (stomach cancer cells), MDA-MB-231 (breast cancer cells), A-549 (lung cancer cells), HCT-116 (colon cancer cells), and A2780 (ovarian cancer cells) with IC_{50} values ranging from 0.5 ± 0.2 to 15.5 ± 2.7 µM [74]. However, in vivo and clinical studies are needed to validate the anti-cancer activity of the obtained derivatives.

4.6. Other Activities

Type 2 diabetes, one of the major endocrine disorders, is characterized by impaired insulin secretion and/or impaired action of insulin at the cellular level. Some plants are known and ethnobotanically used in several parts of the world for their potent antidiabetic activity, *C. album* among them [93]. A study emphasized the antidiabetic potential of methanolic extract of the plant in male Wistar albino rat models. Treatment with a high dose of *C. album* extract (500 mg/kg body weight p.o) resulted in the maximum decrease in fasting blood glucose level (139.5 ± 4.8 mg/dL, $p < 0.01$), while mild and low doses caused a slower reduction (142.2 ± 4.1 mg/dL and 148.3 ±1.5 mg/dL, $p < 0.01$ respectively) in the same at the end of the experiment (after 12 h) [94]. The flavonoid fraction is more effective than the tannin, alkaloid, and saponin

fractions for lowering blood glucose levels [95]. The flavonoid fraction of *C. album* extract at doses of 250 and 500 mg/kg was reported to act by inhibition of α-amylase (IC_{50}—122.18 µg/mL) in a dose-dependent manner. However, some of these doses seem to be supraphysiological and out of realistic range for human nutrition. A general layout representing the important biological activities of the plant and phytochemicals responsible is given in **Figure 2**.

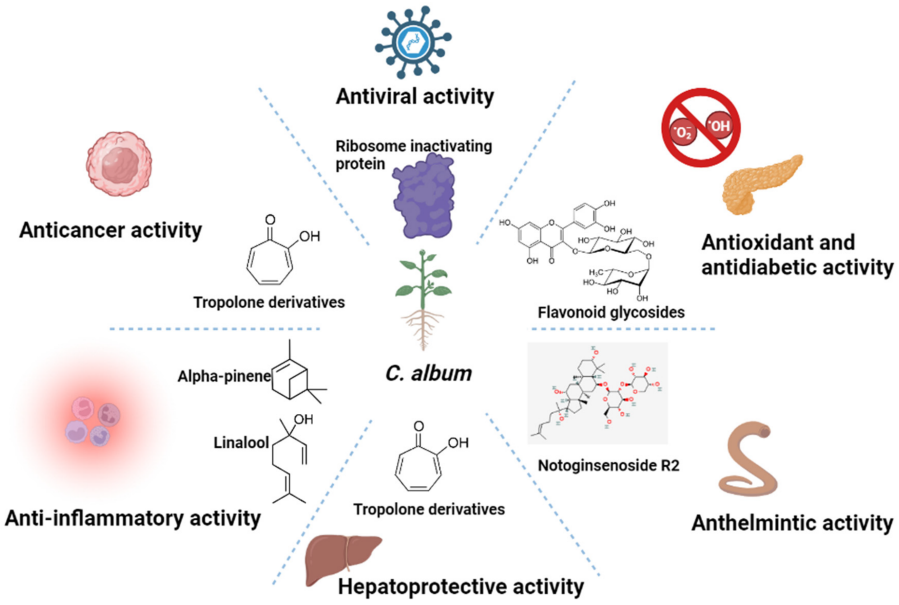

Figure 2. Figure representing important chemical components and corresponding biological activities of *C. album*.

Anti-nociception refers to the decrease in sensitivity of pre-existing painful stimuli. Results from the study revealed the anti-nociceptive activity of crude methanolic extract of *C. album* leaves [96]. The results from a study by Mushtaq and co-authors also corroborate the analgesic and anti-inflammatory activity of the plant. *C. album* resulted in the maximum (64%) inhibition of edema [97]. Interestingly, some studies have also reported the contraceptive action of the plant [98]. The anti-ulcer effect of plant extract has also been documented. It has been reported that alcohol exhibits positive effects against gastric ulcers by significantly decreasing the gastric secretion volume, free and total acidity, and ulcer index [99]. The antirheumatic potential of *C. album* aerial part extract also has been highlighted. The treatment with extract by its capacity to inhibit NF-κB significantly reduced the paw edema and normalized the level of hematological (Hb, RBC, WBC, and ESR) and biochemical (serum creatinine, total proteins, and acute-phase proteins) markers [100].

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