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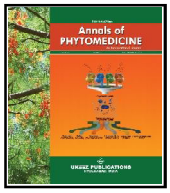

Review Article : Open Access

Cyperus rotundus L.: Phytochemistry and pharmacological activities

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Abstract

History has seen several different medical uses for *Cyperus rotundus* L. (Cyperaceae). Growing naturally in tropical, subtropical, and temperate climates. Ayurveda states that *C. rotundus* rhizomes have historically been used for several conditions, including the treatment of stomach and intestinal diseases, as well as antidiabetic, antimalarial, antidiarrheal, antiinflammatory, antipyretic and analgesic purposes. This review paper evaluates the various medical applications as well as the pharmacognostic, phytochemical, and physicochemical properties of the *C. rotundus* rhizome. Later, these traits could be utilized to quickly identify *C. rotundus* grass, especially in the case of powdered material, and they might even be able to distinguish the medications from the other species.

1. Introduction

Since thousands of years ago, the demands of primary healthcare have been met by plant based medical systems. The medical practices of the ancient world made extensive use of plant resources. More than 80% of the world's population still relies on plant resources, especially in emerging and poor nations. It is important to note that most current pharmaceuticals are derived from plants, which supports many claims about their effectiveness. Herbal treatments made from plants are thought to be safe since they come from natural sources (Mohd *et al*., 2021; Goli *et al*., 2021).

Many local and indigenous people in developing Asian nations continue to fulfil their fundamental requirements from the medicinal plant items that they produce for their livelihood based on the traditional knowledge and experience. The majority of rural and tribal inhabitants, many of which live in utterly isolated locations, are somewhat reliant on forest goods, particularly medicinal herbs. The ethnomedicines obtained from the medicinal plants are thought to be safer, and they have shown to be effective in treating a variety of ailments (Ansari *et al*., 2019; Mehrotra, 2020; Malik *et al*., 2020).

The plant *Cyperus rotundus* L., a member of the Cyperaceae family, is also known as nut grass in English, motha in Hindi, and nagarmotha in Marathi. *C. rotundus* exhibits a wide range of health advantages. Common weeds that grow in highland areas and rice paddies in temperate to tropical climates belong to the genus *Cyperus*. The rhizomes of *C. rotundus* are employed in traditional folk medicines in Asian nations (Singh *et al*., 2016).

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Antidiabetic, antidiarrheal, anti-inflammatory, antipyretic, antiulcer, antimalarial, carminative, astringent, relieve pain, aphrodisiac, anthelmintic, diuretic, antioxidant, analgesic, and for the treatment of stomach and bowel disorders are all characteristics of the pharmacological profile of *C. rotundus* (Jaysweera, 1980; Mansoor *et al*., 2014; Sivapalan, 2018; Taheri *et al*., 2021). *C. rotundus* herb has long rhizomes, six linearshaped, dark green leaves, and little flowers (Stone, 1970). The inflorescence is made up of a few thin branches and 2-4 bracts (Table 1). Like almost half as tall as that of the glumes, the nut is strongly triangular in shape, oblong in shape, and turns yellow to black when fully mature (Rose, 2003). Powder of the dried rhizome of *C. rotundus* has also been subjected to microscopic and FTIR spectroscopic examinations.

Numerous phytochemical analyses of *C. rotundus* reveal the presence of a variety of chemical compounds, including glycerol, myristic, furochromones, stearic acids and linolenic, as well as alkaloids, glycosides, flavonoids, starch, tannins, sitosterol, mono and sesquiterpenes, and fatty oils containing a neutral waxy substance (Dutta *et al*., 1950). The plant grows best in tiny clumps that reach 100 cm tall. Due to its capacity to adapt to a broad number of different soil types, temperatures, elevations, soil pH, and moisture levels, the *C. rotundus* has a wide range of distribution and flourishes in several distinct habitats and situations (Singh *et al*., 2018).

The active pharmaceutical component is the foundation of the contemporary medical system. Considering the importance of the traditional medicine, the present review article was developed based on botany, phytoconstituents, pharmacological activities.

2. Characteristics of *C. rotundus*

*C. rotundus*is a common perennial herb that flourishes under tropical and subtropical climes and can reach heights about 15-30 cm or even 50 cm from a rhizome and has little nutshaped tubers at the base of the stem (Figures 1 and 2). The leaves are oriented in three directions

and are upright. Rhizomes, tubers, and roots are fibrous, highly branching, and covered in bent hairs.

When young, the rhizomes of the plant are white, fleshy, and covered in leaves; as they age, they turn brown, fibrous, or wiry. Rhizomes give rise to underground tubers at spacing of 5 to 25 cm, which continue to multiply and form tuber chains that reach to a significant depth in the soil. Tubers are white, succulent, and between two and three centimeters long when young. As they age, they turn fibrous brown almost or back to white, have a pungent spicy odor when crushed, and are covered in papery scale leaves that have apical buds that grow new plants (Imam *et al*., 2014; Barai *et al*., 2017).

Table 1: Morphological description of organized part of *C. rotundus* plant

S. No.	Organized part	Description
1.	Stem	They are triangular in cross section, smooth 20 to 100 cm high, usually longer than the basal leaves. These culms correspond of flowering axis. The base of the plant is swollen, referred to as a basal bulb, forming a thickened.
2.	Leaf	The basal leaves vary in number, linear, acute, arranged in three directions, 10 to 50 cm long, 5-8 mm wide arising from very compact nodes in basal clusters in three rows, through the center of which the upright fertile stem arises. Blade glabous, shiny, dark green, double folded section with margin.
3.	Fruit	Nuts are ovate or oblong-ovate, 1.5 mm long, 0.8 mm wide, three angled, surmounted by the stigma, olive-gray to brown or black in colour.

Figure 1: *C. rotundus* plant.

Figure 2: *C. rotundus* rhizomes.

2.1 Distribution

The southern Ukraine, Afghanistan, the Caucasus, Iran, Yemen, Middle Asia, Iraq, Saudi Arabia, Syria, Lebanon, Palestine, and Turkey are among the regions where *C. rotundus* is widespread (except northern districts). The western, and eastern Mediterranean's, Atlantic; Minor and Central Asia; tropical Arabia; the Balkan Peninsula; Africa; Australia; North and South America; Europe; Japan; Korea; Taiwan; China; India; Nepal; Sri Lanka; Thailand; Vietnam; Myanmar; Indonesia; and Malaysia are examples of regions outside the former Soviet Union (Ali *et al*., 2016). It is a noxious weed that grows close to farmed crops. It does not fare well in the shadow and grows best on fertile moist soils that have been often cultivated. Common in disturbed settings, and once established, quite tenacious (Radanachaless *et al*., 1994; Galinato *et al*., 1999).

2.2. Microscopic features of *C. rotundus*

As seen in Figure 3, the micrograph of root systems of *C. rotundus* reveals an epidermis composed of parenchymateous cells with typical brownish colour. The cortex is made up of parenchymateous cells, while the hypodermis is made up of 1-2 layers of cells with thick walls. The inner portion is parenchymatous and contains huge intercellular gaps while the outer portion is compressed. Some cells in the cortical region include additional starch grains and brownish oleo-resinous material (Sharma and Singh, 2011). Simple round or enlarged starch grains, quantity of pigmented cells packed with a reddish-brown oleo-resin subject matter, current all through the cortex and stele, vascular bundles encircled by bundle sheaths of fibres, vessels spiral to simple pithed, scattered throughout this region, vessels that are simple round, oval, or elongated, there are lignified secondary wall thickenings in the xylem vessels (Nidugala *et al*., 2013).

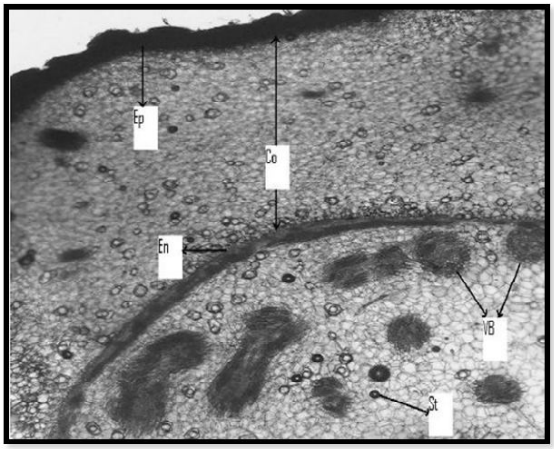


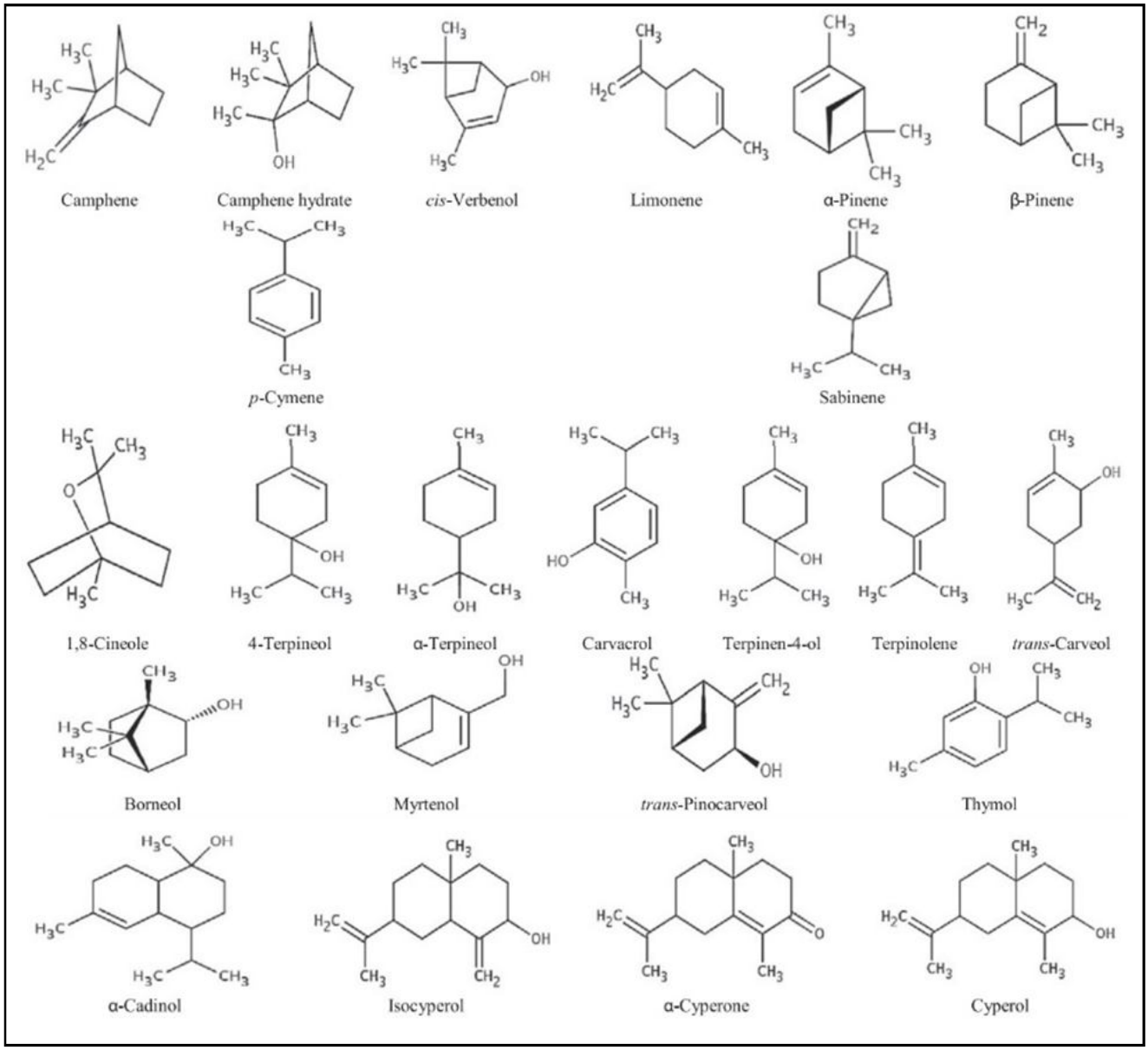
Figure 3: Transverse section of *C. rotundus* rhizomes.

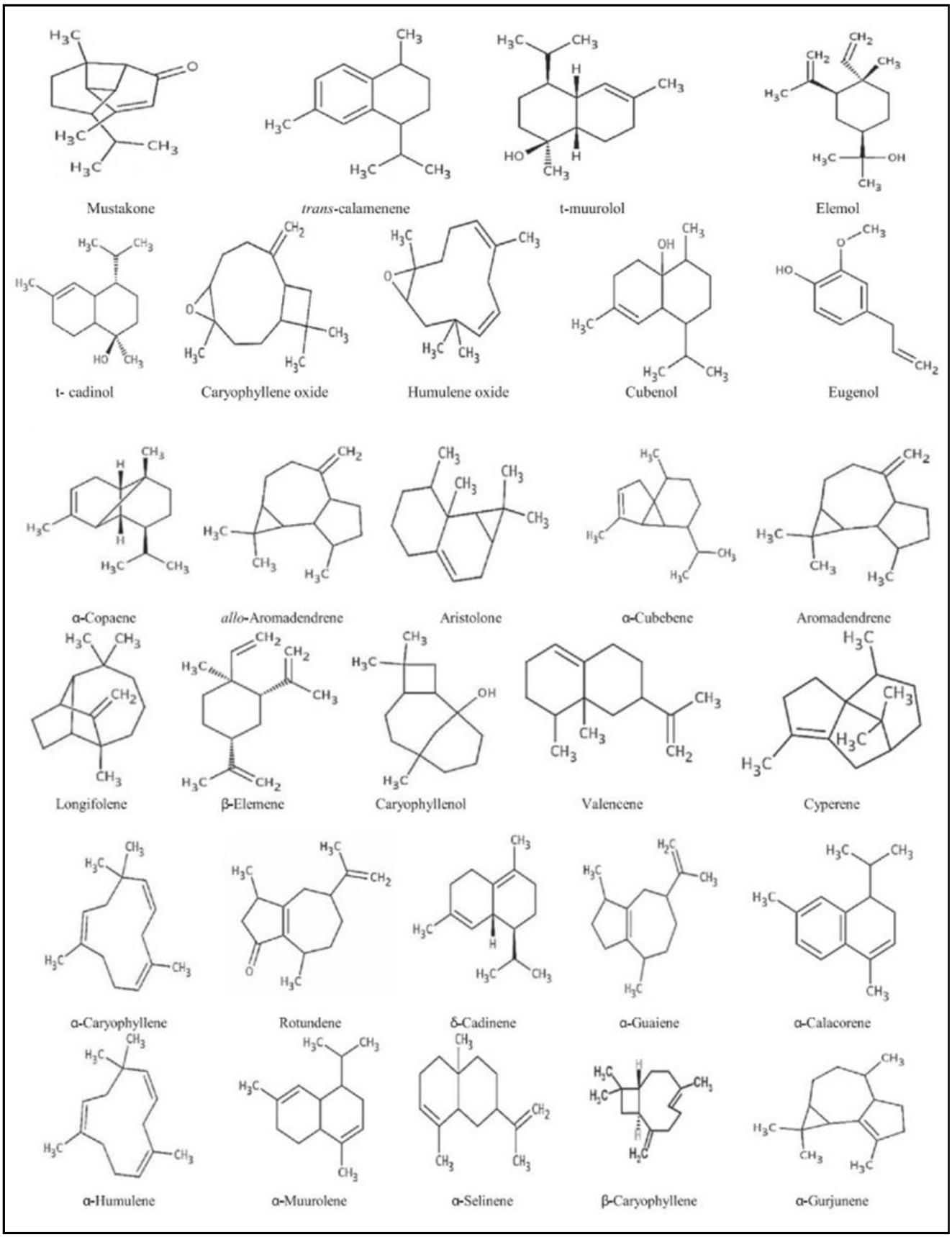
2.3 Chemical constituents of *C. rotundus*

The major chemical constituents are present in such as α-cyperolone, β-cyperone, ρ-cymol, calcium, camphene, copaene, cyperene, cyperenone, cyperol, cyperolone, caryophyllene, cyperotundone, d-copadiene, d-epoxyguaiene, isocyperol, isokobusone, kobusone, limonene, linoleic-acid, linolenicacid, mustakone, myristic acid, oleanolic acid, oleic acid, β-pinene, patchoulenone, rotundene, rotundenol, rotundone, α-rotunol, β-rotunol, β-selinene, selinatriene, sitosterol, stearic acid, sugeonol, and sugetriol as shown in Figure 4 (Zhou and Yin, 2012).

Earlier investigation regarding phytochemical constituents of suggest the presence of alkaloids, flavonoids, glycosides, phenols, tannins, steroids, starch and many novel sesquiterpenoids (Harborne *et al*., 1982; Umerie and Ezeuzo, 2000; Kapadia *et al*., 1967; Trivedi *et al*., 1964; Sivapalan and Jeyadevan, 2012). Sesquiterpene hydrocarbons such as cypera-2,4(15)-diene, isorotundene, norrotundene and the oxygenated compound cyperadione were isolated and identified (Sonwa and Konig, 2001).

The plant*C. rotundus* contains various chemical constituents such as isobutyl lactate, thiazol-4(5H)-one5-(4-nitrobenzylidenol)-2-phenyl, cis-pinen-3-ol, pyranone, trans-p-mentha-2,8-dienol, β-santalol, cis-13,16-docasadienoic acid, cis-10-nonadecenoic acid, β-vatirenene, β-nootkatol, elema-1,3-dien6a-ol, α-copaen11-ol, 25,26-dihydroxy-vitamin D3 yperolundone D-copadiene, D-fructose, D-glucose, D-epoxyguaiene, Flavonoids, isocyperol, isokobusone, kobusone, γ-cymene, limoncnc,linolcic-acid, magnesium manganese, linolenic-acid, mustakonc, ginkgetin, amentoflavone, isoginkgetin and sciadopitysin (Jain and Das, 2016; El Wakil *et al*., 2019). The rhizome of *C. rotundus* was composed essential oil, mainly of anethole (16.2 %), β-selinene (23.7%), cuminaldehyde (9.2 %), stearic acid (8.7 %), arachidic acid (9.4 %) and α-cyperone (8.1 %) (Ying and Bing, 2016).




Mustakone
trans-calamenene
t-muurolol
Elemol
t- cadinol
Caryophyllene oxide
Humulene oxide
Cubenol
Eugenol
α-Copaene
allo-Aromadendrene
Aristolone
α-Cubebene
Aromadendrene
Longifolene
β-Elemene
Caryophyllenol
Valencene
Cyperene
α-Caryophyllene
Rotundene
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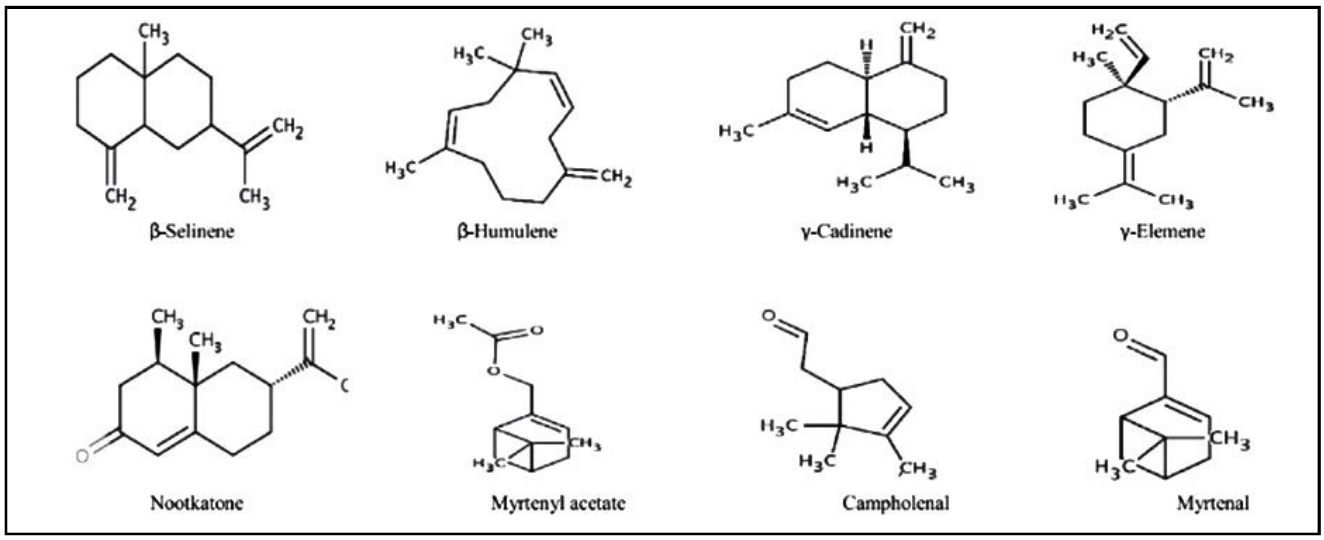

Figure 4: Chemical composition of *C. rotundus* rhizomes (Peerzada *et al.*, 2015).

2.4 Folkloric and ethnomedicinal claims of *C. rotundus*

As a vermicide, kids are provided two teaspoonfuls of the *C. rotundus* tubers decoction daily for three days. Tuber juice is used to treat skin problems by purifying the blood (Nath *et al.*, 2009). The rooted cuttings are utilized for weight loss, gynaecological, hair stimulation, uric acid, gastrointestinal, and psychological diseases (Ghannadi *et al.*, 2012).

2.5 Medicinal uses of *C. rotundus*

C. rotundus is a plant that is frequently used in traditional medicine to cure a variety of illnesses all over the world (Kamala *et al.*, 2018a). Ayurvedic system of medicine recommends using the rhizomes of *C. rotundus* as an diaphoretic, analgesic, antiarthritic, diuretic, astringent, antispasmodic, antipyretic, antidiabetic, cytoprotective, antiinflammatory, antimutagenic, antimicrobial (Daswani *et al.*, 2011; Kaur *et al.*, 2020) antioxidant and apoptotic, aromatic, carminative, emmenagogue and antitussive (Sivapalan, 2018). In light of the constituents it contains, such as the numerous enzymes for minerals and carbohydrates that work as a stimulus for various biochemical events and aid in digestion, it may be a useful treatment for indigestion. Additionally, it helps with the nutritional treatment of metabolic and psychotic conditions (Anonymous, 1950).

They are also used to treat blood disorders (Srivastava *et al.*, 2013), such as dyspepsia, colic, diarrhea, nausea and vomiting, flatulence, dysentery, fever, renal and vesical calculi, intestinal parasites, cough, malaria, bronchitis, skin diseases, amenorrhea, wounds, inadequate lactation, memory loss, insect bites, dysmenorrhea, indigestion, dysuria, food poisoning, bronchitis (Chopra *et al.*, 1986; Bown, 1995).

3. Pharmacological activities of *C. rotundus*

3.1 Anti-inflammatory activity

The alcohol extract (70%) of *C. rotundus* exhibits anti-inflammatory activity against carrageenan induced edema and has been successful in treating arthritis brought on by formaldehyde in albino rats. When carrageenan induced edema in albino rats was induced, the triterpenoid that was isolated through chromatographic separation from the ethyl acetate extract of the rhizomes exhibited anti-inflammatory activity. Additionally, utilized as protection against inflammatory bowel illnesses is *C. rotundus*. The extract also reduced the generation of free radicals. Taking these findings together, it was concluded that now the methanol extract of *C. rotundus* rhizomes might be used to create an anti-inflammatory new drug for such treatment of inflammatory illnesses caused by free radicals (Seo *et al.*, 2001; Sundaram *et al.*, 2008).

C. rotundus tuber extract has anti-inflammatory activity on carrageenan induced paw edoema in albino wistar rats. Six rats were placed in each of the eight groups for the experiment. All the rats received 1% carrageenan injections to cause paw edoema, and the paw volume was assessed at regular intervals after receiving solvent extracts in ether, distilled water, and ethanol. The outcomes were contrasted between the group receiving conventional doses of indomethacin and the 1% tween 80 control group. The ethanolic extract showed the highest percentage suppression of paw edoema, which was comparable to that of the common anti-inflammatory medicine indomethacin, demonstrating that *C. rotundus* had anti-inflammatory action (Chithran *et al.*, 2012).

3.2 Analgesic activity

The analgesic activity of the raw extract of *C. rotundus* was assessed using the tail flick method on mice, however the ethanol extract and hot water extract rotundus at 500 mg/kg and 12.7 g/kg was inert in the hot plate technique and acetic acid test in addition to being non-analgesic. The crude extract is given orally at a dose of 300 mg/kg body weight. Highly considerable analgesic action was demonstrated when (dispersed in 0.9% saline solution) (Peerzada *et al.*, 2015).

The essential oil of *C. rotundus* was tested for its analgesic properties. The right hind paw of swiss albino rats was injected with 0.05 ml of 2.5% formalin to cause pain 30 min after the oral administration of indomethacin (10 mg/kg), 1% CMC, and essential oils (250, 500 mg/kg). Phase I, which lasts from 0 to 5 min after the formalin injection, and phase II, which lasts from 15 to 30 min, measures the number of licks of the formal ininjected paw that represent pain at larger doses, it was shown that the essential oils of *C. rotundus* reduce both neurogenic and inflammatory pain, but at lower doses, only

inflammatory pain was inhibited. This demonstrates the analgesic action of *C. rotundus* essential oils (Biradar *et al*., 2010).

3.3 Antiarthritic activity

In male wistar albino rats, the antiarthritic effect of *Cyperus* species essential oils was investigated. Group I acted as the arthritis control group, Group II received diclofenac sodium as the conventional treatment, Groups III and IV received 250 and 500 mg/kg of *C. esculentus* essential oil, respectively, and Groups V and VI received 250 and 500 mg/kg of *C. rotundus* essential oil. After measuring the baseline paw volume using a plethysmometer, arthritis was produced by injecting the left hind paw with 0.1 ml of formaldehyde 2% v/v in normal saline. Paw volume was measured every day over the course of the 10 day therapy. Rats given 500 mg of the essential oils of *C. esculentus* and *C. rotundus* had much less left hind paw edema than rats given diclofenac. When compared to the 81.37% inhibition shown in diclofenac treated rats on day 21, *C. rotundus* and *C. esculentus* showed a 75.54 and 76.58% inhibition in paw edema on the tenth and eleventh days, respectively. This demonstrates the antiarthritic properties of *Cyperus* species essential oils (Biradar *et al*., 2010).

3.4 Antipyretic activity

A subcutaneous injection of a solution of dehydrated yeast in acacia in saline solution causes pyrexia in albino rats, which the alcohol extract of *C. rotundus* exhibits antipyretic efficacy against (Singh *et al*., 2012). Column chromatography was used to repeatedly separate the *C. rotundus* rhizome's methanol extract into its soluble fractions for use in studying the structure of the separated chemicals utilizing UV, IR, H and CNMR, and MS spectra (Rajamanickam and Rajamanickam, 2016).

The subcutaneous injection of a suspension of dried Brewer's yeast in gum acacia in normal saline caused albino rats to experience pyrexia, which was effectively treated with the alcohol extract of *C. rotundus*. When applied to the same animal model, the extract was found to have an antipyretic effect comparable to that of acetyl salicylic acid (Gupta *et al*., 1971).

3.5 Wound healing activity

A nitro furazone ointment (0.2% w/w) standard drug was compared to an ethanolic extract of *C. rotundus* for wound healing activity in three separate rat models: the excision, the incision, and the dead space wound model. The ethanolic extract of *C. rotundus* was applied in ointment form. When using 2% of the weight of the ethanolic extract of *C. rotundus*, 100% wound closure was seen on day 18. The wound healing process was tracked by wound contractibility, time of wound closure, and tensile strength. It was revealed to have comparatively greater wound healing activity than standard nitro furazone (Puratchikody *et al*., 2006).

3.6 Antimicrobial activity

By using the agar disc diffusion method, the *in vitro* antibacterial activity of both ethanolic and aqueous extracts was assessed. While the aqueous extract was ineffective, the ethanolic extract proved effective against all the tested bacterial strains (Sivapalan, 2018). Other research used the disc diffusion method to demonstrate the broad spectrum antibacterial action of acetone and ethanol extracts. Testing for antimicrobial activity was done on bacteria that cause human diseases. Numerous research incorporating microbe genera and species, the existence of saccharides, herb growth conditions, and extraction methods have demonstrated the antibacterial efficacy of *C. rotundus* extract (Sharma and Singh, 2011a; Haghgoo *et al*., 2017).

3.7 Anticandida activity

A total of 35 medicinal herbs from Brazil were investigated for their anticandida potential. The anticandida action of essential oils was good, but ethanolic extract was ineffective at all doses tested (Duarte *et al*., 2005).

3.8 Antiviral activity

The antiviral efficacy of *C. rotundus* hydroalcoholic extract and 41 Egyptian medicinal herbs were tested. Three viruses HSV (herpes simplex-1 virus), POLIO (poliomyelitis-1 virus), and VSV were tested against the extract (vesicular stomatitis virus). The end point titration approach was used to determine antiviral activity. *C. rotundus* had HSV virucidal action (Soltan and Zaki, 2009).

3.9 Antifungal activity

Rhizome was active towards *Phytophthora capsid*, *Colletotrichum chardonianum* and *Sclerotinia scleroliorum* when tested on an agar plate. Undiluted fresh shoot water extract on an agar plate had no effect on *Helminthosporium turcicum* (Mokkhasmit *et al*., 1971).

3.10 Antimalarial activity

The isolated pure chemicals from *C. rotundus* tubers, *Zanthoxylum gilletii* root bark, and *Margaritaria discoidea* root bark were proven to have antimalarial action. α-cyperone from *C. rotundus*, N-isobutyldeca-2,4-dienamide from *Z. gilletii*, and securinine from *M. discoidea* were the substances with the most antimalarial action. The compound with the most potential as an antimalarial was determined to be the b-selinene autoxidation products derived from *C. rotundus* (Weenen *et al*., 1990).

Sesquiterpenes (patchoulenone, caryophyllene alpha-oxide, 10,12-peroxycalamenene, and 4,7-dimethyl-1-tetralone) isolated from *C. rotundus* that have antimalarial action. These substances had antimalarial properties. 10,12-peroxycalamenene had the greatest impact, with an EC_{50} of 2.33 106 M. (Thebtaranonth *et al*., 1995).

C. rotundus was investigated for its antiplasmodial properties. The growth suppression of asexual erythrocytic stages of chloroquine (CQ)sensitive (3D7) and (CQ) resistant (INDO) strains of *Plasmodium falciparum* in culture was evaluated using ethyl acetate extract of *C. rotundus*. The experiment was performed using fluorescence based SYBR Green I. The antiplasmodial activity of the *C. rotundus* ethyl acetate extract was extremely good (IC_{50} 10-10 g/ml) (Kaushik *et al*., 2013).

3.11 Ovicidal and larvicidal effect

Study was done on the ovicidal and larvicidal effects of *C. rotundus* essential oils. *Aedes albopictus* eggs and larvae have been the subject of studies (Skuse). The essential oil was applied to the eggs and fourth instar larvae for 24 h at concentrations ranging from 5 to 150 ppm. The essential oil's fatal dosage (LD_{50}) value of 20 ppm and half maximal effective concentration (EC_{50}) value of 5 ppm, respectively, demonstrated *C. rotundus* potent ovicidal and larvicidal action (Kempraj and Bhat, 2008).

3.12 Gastroprotective activity

The gastro protective activity of *C. rotundus* rhizome extract was investigated by injuring the stomach mucosa in male wistar albino rats through ischemia and reperfusion. At doses of 100 and 200 mg/kg of *C. rotundus*, the extract was administered. The extracts significantly preserve the stomach mucosa of the rat's given treatment, preventing injury (Guldur *et al*., 2010).

The methanolic extract of *C. rotundus* rhizome was investigated for its gastroprotective properties. In male wistar albino rats, ischemia and reperfusion caused damage to the stomach mucosa. The dosage of the extract was 100 and 200 mg/kg of *C. rotundus*. The extracttreated animals underwent 60 min of reperfusion after 60 min of ischemia. Albino rats given *C. rotundus* extract had considerably reduced mean ulcer indices than control rats. When compared to untreated rats, who had decreased antioxidant activity of GSHPx and elevated MDA levels, the rats treated with *C. rotundus* rhizome extract showed improved antioxidant activity of GSH-Px and decreased MDA levels. According to the findings, *C. rotundus* extract significantly protects against injury to the stomach mucosa (Muhammet *et al*., 2010).

3.13 Antidiarrheal activity

After ingesting a *C. rotundus* root extract prepared in castor oil using petroleum ether, methanol and ethyl acetate, mice had diarrhea. In relation to the fraction of methanolic, ethyl acetate, and petroleum ether at a dosage of 250 mg/kg were much more active than the control. No signs of an antidiarrheal effect were present. The antidiarrheal properties of *C. rotundus* tubers have also been studied in relation to enterotoxigenic *E. coli*, and *Shigella flexner*. This decoction affected both the production of cholera toxin and the outcomes of heat labile toxin (Kamala *et al*., 2018).

The castor oil induced diarrhoea in mice was treated with a methanolic, petroleum ether, and ethyl acetate extract of the *C. rotundus* rhizome, which showed antidiarrheal action. 250 mg/kg of the methanolic and petroleum ether fractions, which were administered orally in dosages of 250 and 500 mg/kg, each shown considerable activity, with the former being more active than the control. The ethyl acetate fraction did not show antidiarrheal effect (Uddin *et al*., 2006).

The antidiarrheal efficacy against enteropathogenic *E. coli*, enteroinvasive *E. coli*, and *Shigella flexneri* was also investigated using the decoction of *C. rotundus* tubers. By assessing the impact on colonisation, the adhesion of these pathogens to HEP-2 cells was used to assess the antidiarrheal activity. The decoction decreased bacterial invasion and adhesion to HEP-2 cells. The decoction also had an impact on how heat labile toxin and cholera toxin were produced and behaved. Due to the fact that the decoction of *C. rotundus* lacks significant antimicrobial activity, it was discovered that the antidiarrheal effect is carried out by means other than the direct killing of pathogens (Daswani *et al*., 2011).

3.14 Anthelmintic activity

When given to mice, the hot water leaf extract of *C. rotundus* exhibits no effect on, *Trichostrongylus axei*, *Nippostrongylus brasiliense* and *Syphacia obvelata*. Mice were given an oral hot water extract of the tuber, which had no effect on *S. obvelata*, *N. brasiliense*or *T. axei* (Singhal, 1976; Nagarajuand Rao, 1990).

The anthelmintic activity of methanolic extractof on Indian earthworm *Pheretima posthuma* was evaluated using two different concentrations (20 and 50 mg/ml). The reference drug was albendazole. By keeping track of how long it took the earthworms to become paralysed and die, anthelmintic activity was determined. At a concentration of 50 mg/ml, the methanolic extract of *C. rotundus* demonstrated considerable anthelmintic action, and the outcome was equivalent to that of conventional treatments (Kasala *et al*., 2016).

3.15 Antiulcer activity

The rhizome powder of *C. rotundus* exhibited ulcerpreventive properties. Two distinct animal models were used for the investigation. Histamine (50 mg base i.p.) was used to cause gastric ulcers in guinea pigs, while aspirin (500 mg/kg orally) was used to cause ulcers in albino rats. The *C. rotundus* rhizome powder was administered orally 45 min before the histamine and one hour before the aspirin. In both situations, *C. rotundus* significantly reduced the ulcer index and had results that were equivalent to those of the reference drug ranitidine. The strong antioxidant activity of *C. rotundus* is what causes it to have antiulcer properties (Mohammad *et al*., 2012).

3.16 Antiemetic activity

The antiemetic properties of *C. rotundus* roots were investigated. The pigeons, which ranged in weight from 200 to 300 g, were split into 4 groups, each with 10 birds. Reserpine was given to group I at a dose of 0.5 mg/kg im; to group II at a dose of 4 mg/kg, im of triflupromazine; to group III at a dose of 80 mg/kg, im *C. rotundus* followed by 45 min of reserpine; and to group IV at a dose of 80 mg/kg, im *C. rotundus* 24 h before reserpine treatment. Vomiting incidence and start time were tracked for 4 h, and the findings were analysed using the Chi-square test. Reserpine's emetic effect was totally prevented in the group that got the antiemetic medication triflupromazine, whereas reserpine completely caused vomiting in group I, with an average time for the commencement of vomiting of 63 to 99 min. 83% of the birds treated with *C. rotundus* 45 min before reserpine were shielded from the drug's emetic effects, whereas the group treated with *C. rotundus* 24 h before reserpine delivery was unable to do so. According to the study, *C. rotundus* was more successful in counteracting the emetic effects of reserpine when administered 45 min beforehand (Shinde *et al*., 1988).

3.17 Antialcoholic activity

At a dosage of 5.0 ml/animal inside the rats' diet, the fermenting tuber of *C. rotundus* proved effective. The effects of alcohol on electroencephalogram, electrocardiogram, liver fat deposition, haemorrhage symptoms, demyelination, and spongiosis were reversed by a dose administered daily for 90 days (Shanmugasundaram *et al*., 1986)

3.18 Anticonvulsant activity

Mice of both sexes received intraperitoneal injections of a 70% ethanolic extracts of fresh roots, which demonstrated activity against strychnine and metrazoleinduced convulsions. It was shown that the rhizome of *C. rotundus* could lessen the intensity and length of a PTZ induced seizure. It also revealed that a hydroalcoholic extract of this plant at the higher dose could greatly shorten a phase 5 seizure's duration (Chang *et al*., 1980; Khalili *et al*., 2011).

In albino rats, the rhizome of *C. rotundus* was tested for its ability to prevent seizures brought on by pentylenetetrazole (PTZ) and maximum electroshock (MES). Rats were used to measure the duration of tonic flexion, tonic extensor, clonus, stupor, and recovery phase in order to determine the extract's anticonvulsant effect. The oral treatment of ethanol extract (100 mg/ kg) significantly decreased the length of the convulsion and hind limb extension. The outcome was comparable to that of the standard phenytoin (25 mg/kg, i.p.) and diazepam (4 mg/kg, i.p.). The rich flavonoids in *C. rotundus* can be ascribed for the anticonvulsant action (Shivakumar *et al*., 2009).

3.19 Neuroprotective effect

An investigation into the neuroprotective effects of *C. rotundus* rhizome extract on SIN-1-induced protein nitration and nitric oxide production was conducted. 500 M donor SIN-1 for nitric oxide (3-morpholinosydnonimine hydrochloride). Reactive nitrosative species produced by nitric oxide, such as peroxynitrite (ONOO), induce protein tyrosine nitration, which alters the structural makeup of the affected proteins and causes their deactivation. According to the study, pre-treating human neuroblastoma SH-SY5Y cells with *C. rotundus* rhizome extract reduced SIN-1 induced damage to the mitochondria and plasma membrane by 80 and 24%, respectively. This was demonstrated by MTT and LDH tests. Immunoblot analysis proved that the rhizome extract of *C. rotundus* replaced the SOD and CAT enzyme activity depletion caused by SIN-1. Bcl-2 and caspase-3, which control the cell's proteolytic damage, are apoptotic indicators that are effectively increased by pre-treatment with *C. rotundus* rhizome extract. *C. rotundus* rhizome extract repaired the cellular, nuclear, and mitochondrial integrity that peroxynitrite had harmed. This demonstrates that *C. rotundus* rhizome extract can prevent neuronal damage due to its oxidonitrosative and antiapoptotic effects. (Kumar *et al*., 2013).

3.20 Antihyperglycemic activity

The different fractions (chloroform, ethyl acetate, acetone, and methanol) of hydroethanol extract, had antihyperglycemic effects in Sprague Dawley rats in alloxan induced diabetes model. Due to the high level of polyphenols, the antioxidant property is responsible for its antihyperglycemic effect (Raut and Gaikwad, 2012).

The newly discovered (2RS, 3SR)-3,42 ,5,6,7,8-hexahydroxyflavane and three previously identified stilbene dimers (cassigarol E, scirpusin A, and b) from *C. rotundus* were tested for their ability to block the carbohydrate metabolizing enzymes α-glucosidase and α-amylase. Cassigarol E, scirpusin A, and B all inhibited α-glucosidase activity, while only α-amylase activity was affected by (2RS, 3SR)- 3,42 ,5,6,7, and 8-hexahydroxyflavane and cassigarol E. Each of the four substances demonstrated a substantial amount of DPPH radical scavenging ability. This demonstrated a pronounced antihyperglycemic action of the separated chemicals (Tran *et al*., 2014).

3.21 Antiobesity activity

The antiobesity activity of the aqueous tuber extract of *C. rotundus* was assessed in obese albino rats fed a high fat cafeteria meal. Six groups of rats were used: group I served as the normal control group, group II as the disease control group, group III, group IV, and group V served as the test groups, receiving doses of 100, 200, and 300 mg/ kg body weight of the aqueous extract of *C. rotundus* along with a highfat cafeteria diet, and group VI served as the standard group. As a benchmark, orlistat (50 mg/kg) was employed. Obesity was caused by the highfat cafeteria food that was given to experimental groups for 40 days. While aqueous extract treatment resulted in a considerable decrease in weight (Athesh *et al*., 2014).

3.22 Cardioprotective and antihyperlipidemic activity

Researchers discovered that a methanolic extract of the *C. rotundus* rhizome has cardioprotective and antihyperlipidemic properties. For the experiment, male albino rabbits were utilized. There were eight groupings of the creatures. Inducing myocardial infarction in rabbits required 85 mg/kg body weight of isoproterenol (ISO). Groups III, IV, and V were given oral doses of 100, 150, and 200 mg/kg of *C. rotundus*, respectively, over a period of 21 days. Group I functioned as the normal control. Group II was the ISO (85 mg/kg) control. Groups VI, VII, and VIII received pre-treatment doses of 100, 150, and 200 mg/kg of *C. rotundus*, respectively, for 21 days before receiving ISO injections over the course of two days serum lipids, cardiac marker enzymes, and antioxidant enzymes were evaluated. Serum lipid and cardiac marker enzyme levels that were raised owing to ISO injection were significantly reduced, while antioxidant enzyme levels that had been diminished because of ISO injection were restored. This demonstrated the therapeutic potential of *C. rotundus* rhizome extract in the treatment of myocardial infarction and excessive blood lipid levels. In addition to exhibiting acetylcholine esterase inhibitory action and anxiolytic effects, the hydroalcoholic extract of the rhizome of *C. rotundus* is beneficial in avoiding oxidative stress and preserving DNA from H_2O_2induced damage (Jahan *et al*., 2012; Kumar *et al*., 2014).

3.23 Antiplatelet activity

The ethanolic extract of *C. rotundus* was said to have antiplatelet action. The effect of the extract and eight of its component chemicals on platelet aggregations *in vitro*, *ex vivo*, and bleeding time were studied. For the platelet aggregation experiment, Sprague Dawley (SD) rats were employed, while ICR mice were used for the tail bleeding time investigation. An *in vitro* investigation on platelet aggregation revealed substantial and concentration based inhibitory effects on platelet aggregation caused by collagen, thrombin, and arachidonic acid. Out of the eight components, (+)-nootkatone was shown to have the most inhibitory impact on rat platelet aggregation both *ex vivo* and *in vitro*. Additionally, the mice's bleeding duration was lengthened by (+)-nootkatone and the *C. rotundus* extract. Therefore, *C. rotundus* extract and (+)-nootkatone, one of its active ingredients, can be utilized to prevent cardiovascular disorders connected to platelets. (Seo *et al*., 2011).

3.24 Coronary vasodilator activity

When administered intravenously, an aqueous extract of a rhizome of *C. rotundus* provides good outcomes in cats, rabbits, and frogs (Kapadia *et al*., 1967).

3.25 Hepatoprotective activity

Researchers looked at the hepatoprotective properties of a *C. rotundus* ethyl acetate rhizome extract against rat liver damage brought on by carbon tetrachloride. Alkaline phosphatases (ALP), aspartate transaminase (AST), alanine transaminase (ALT), and total bilirubin levels were measured. A 100 mg/kg oral dosage had a notable protective effect. Histopathological analysis was also used to support the test (Suresh Kumar and Mishra, 2005).

3.26 Antihistamine activity

Male albino rats were used to test the antihistamine effectiveness of the polyherbal formulation, which contains *C. rotundus* rhizome as one of its ingredients. Six rats each made comprised each of the four groups that the rats were split into. Each rat received a 0.1 ml injection of histamine into the hind paw. Group I served as an untreated negative control group; group II functioned as the standard group and received oral administration of standard phenyl butazone (100 mg/kg). As test groups, groups III and IV were given, respectively, 200 mg/kg and 400 mg/kg of the herbal composition. At regular intervals of 0-240 min, the paw volume rise following the development of oedema was assessed. The amount of swelling was measured using a plethysmometer. Rats' reduced paw volume demonstrated the herbal formulation's antihistaminic properties (Sangeetha *et al*., 2014).

3.27 Antiallergic activity

The isolated sesquiterpene derivatives (valencene, nootkatone, and caryophyllene α-oxide), monoterpene derivatives (β-pinene, 1,8-cineole, and limonene) and 4-cymene from the 70% ethanolic extract of *C. rotundus* rhizome were assessed for their antiallergic activity both *in vitro* and *in vivo*. Valencene, a component of the extract, at a concentration of 300 g/ml effectively blocked the release of b-hexosaminidase by antigenstimulated RBL-2H3 cells and 5-lipoxygenase (5-LOX)-catalyzed leukotrienes (LTs) in RBL-1 cells. Inhibiting Lyn phosphorylation, the first activation process, in RBL-2H3 triggered by immunoglobulin E prevented b-hexosaminidase from degranulating. Valencene and nootkatone, when given orally at 50-300 mg/kg, effectively decreased the delayed type hypersensitivity response caused by picryl chloride in mice. This demonstrated that monoterpenes, but not sesquiterpenes extracted from *C. rotundus* rhizome, contribute to preventing the allergic response in mice. (Jin *et al*., 2011).

3.28 Antioxidant activity

When given to mice by stomach intubation at such a dose of 1.6 g/kg, the dehydrated rhizome of the methanol extract rotundus had no effect on the liver's lipid peroxidation caused by ethanol. The rhizome of *C. rotundus* was extracted crudely, and it was found to have significant antioxidant activity. The rhizome extract from *C. rotundus* in acetone displayed exceptional activity (Tanaka *et al*., 1980).

Alcoholic extract ofrhizome shows *in vitro* antioxidant activity via non-enzymatic haemoglobin glycosylation method (Pal and Dutta, 2006). Since haemoglobin glycosylation is an oxidation reaction and antioxidants will inhibit the reaction, the degree of haemoglobin glycosylation inhibition directly relates to the antioxidant capacity. The plant extract with high concentration of polyphenols, flavonoids, ascorbic acid, and other active ingredients may be the cause of its antioxidant potential. Based on their polarity, around 70% acetone extract had the greatest antioxidant activity when compared to other solvent extracts (Kamala *et al*., 2018).

4. Conclusion

This study makes an effort to compile all of the information that has been published about *C. rotundus*, with a particular emphasis on recently released research. The rhizomes of *C. rotundus* and its extracts have been widely employed in traditional medicine and ayurveda for a variety of therapeutic purposes. It is one of the top medicines in Ayurveda. The data given in the review comes from studies conducted *in vitro*, *in vivo*, and during clinical trials, which have demonstrated the pharmacological mechanisms and characteristics of *C. rotundus*. Most of the research publication reveals that the all the medicinal properties of *C. rotundus* is due to the presenceof variety of phytochemicals.

The morphological, microscopic, and pharmacognostic properties of *C. rotundus* are covered in the current review. These traits will serve as a standard reference for identifying and separating *C. rotundus* rhizomes out of its imitators and adulterants. The evaluation report would help identify the natural product in the future. The medicinal properties of *C. rotundus* includes anti-inflammatory, analgesic, antiarthritic, antipyretic, wound healing, antimicrobial, anticandida, antiviral, antifungal, antimalarial, ovicidal and larvicidal, gastroprotective, antidiarrhea, anthelmintic, antiulcer, antiemetic, antialcoholic, anticon vulsant, neuroprotective, antihyperglycemic, antiobesity, cardioprotective and antihyperlipidemic, antiplatelet, coronary vasodilator, hepatoprotective, antihistamine, antiallergic and antioxidant activity. *C. rotundus* is frequently used in traditional medicine. From various plant sections, a number of chemical compounds have been identified; nevertheless, the precise actions and related processes for the pharmacological effects of many of them uncertainty surrounds these substances isolated from *C. rotundus* but recognized as such. The safety and effectiveness of medicinal plants in the prevention and treatment of many chronic diseases has led to a significant growth in their usage in the modern era. Around the world, there is a great deal of research being done on herbal plants and ayurvedic remedies. There is a need for more study to clarify the mechanism of action due to its broad pharmacological potential.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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