INTRODUCTION

Centella asiatica (L.) Urban syn. synonym Hydrocotyle asiatica Linn. commonly known as Indian Pennywort, belongs to the family Apiceae (previously known as Umbelliferae). Centella asiatica is one of the chief herbs for treating skin problems, to heal wounds, for revitalizing the nerves and brain cells, hence primarily known as a "Brain Food" in India. The use of Centella in food and beverages has increased over the years basically due to its beneficial functional properties. Its potential antioxidant, antimicrobial, cytotoxic, neuroprotective and other activities have been widely claimed in many reports and basically is very much related to its properties and mechanism of action of the plant's bioactive constituents namely the triterpene acid (asiatic acid, madecassic acid), triterpenic saponin (madecassoside and asiaticoside), flavanoids and other phenolic compounds. The present review is an up-to-date and comprehensive literature analysis of the chemistry and various health beneficial functional properties of the Centella plant.

Keywords: Centella asiatica, Functional properties, Bioactive constituents, Health benefits

FUNCTIONAL PROPERTIES OF CENTELLA ASIATICA (L.): A REVIEW

VASANTHARUBA SEEVARATNAM1, P.BANUMATHI1, M.R.PREMALATHA1, SP.SUNDARAM2 and T.ARUMUGAM3

1Dept. of Food Science and Nutrition, Tamil Nadu Agricultural University, Madurai, India, 2Dept. of Agric. Microbiology, Tamil Nadu Agricultural University, Madurai, India, 3Dept. of Horticulture, Tamil Nadu Agricultural University, Madurai, India.

Received: 03 July 2012, Revised and Accepted: 11 Aug 2012

ABSTRACT

Centella asiatica (L.) is a perennial, creeper, faintly aromatic and a valuable medicinal herb of both Old World and the New World. It is widely distributed throughout tropical and subtropical regions of World. The use of Centella in food and beverages has increased over the years basically due to its beneficial functional properties. Its potential antioxidant, antimicrobial, cytotoxic, neuroprotective and other activities have been widely claimed in many reports and basically is very much related to its properties and mechanism of action of the plant's bioactive constituents namely the triterpene acid (asiatic acid, madecassic acid), triterpenic saponin (madecassoside and asiaticoside), flavanoids and other phenolic compounds. The present review is an up-to-date and comprehensive literature analysis of the chemistry and various health beneficial functional properties of the Centella plant.

INTRODUCTION

Centella asiatica (Linn.) Urban syn. synonym Hydrocotyle asiatica Linn. commonly known as Indian Pennywort, belongs to the family Apiceae (previously known as Umbelliferae). Centella asiatica is one of the chief herbs for treating skin problems, to heal wounds, for revitalizing the nerves and brain cells, hence primarily known as a "Brain Food" in India. The use of Centella in food and beverages has increased over the years basically due to its health benefits such as antioxidant, as anti-inflammatory, wound healing, memory enhancing property and many others. The potential of Centella as an alternative natural antioxidant especially of plant origin and its protection against age-related changes in brain antioxidant defense system, have notably increased in recent years. According to the reports of Export and Import Bank of India Centella asiatica is one of the important medicinal plants in the International market of medicinal Plant Trade. However, the wild stock of this plant species has been markedly depleted, because of its large scale and unrestricted exploitation coupled with limited cultivation and insufficient attempts for its replacement has been made. Moreover, now it has been listed as Threatened plant species by the International Union for Conservation of Nature and Natural Resources (IUCN), and also as an endangered species. The plant is known as the following vernacular names: Thankuni (Bengali), Mandookparini (Hindi), Peguga (Malay), Kodagam (Malayalam), Gotukola (Sinhalese), Vallarai (Tamil) and Bekaparanamu (Telugu).

Morphology

Centella asiatica (L.) is a prostrate, faintly aromatic, stoloniferous, perennial, creeper herb, attains height up to 15 cm (6 inches). Stem is glabrous, striated, rooting at the nodes. Centella asiatica flourishes extensively in shady, marshy, damp and wet places such as paddy fields, river banks forming a dense green carpet and rather than clayey soil, the sandy loam (60% sand) is found to be the most fertile soil for its regeneration. The leaves, 1-3 from each node of stems, long petioles, 2-6 cm long and 1.5-5 cm wide, orbicu lar-reniform, with sheathing leaf base, crenate margins, glabrous on both sides. Flowers are in fascicled umbels, each umbel consisting of 3-4 white to purple or pink flowers, flowering occurs in the month of April-June. Fruits are borne throughout the growing season in approx 2 inches long, oblong, globular in shape and strongly thickened pericarp. Seeds have pedulous embryo which are laterally compressed.

Centella asiatica found throughout tropical and sub tropical regions of India up to an altitude of 600m. The plant is indigenous to South-East Asia, India, and Sri Lanka, parts of China, the Western South Sea Islands, Madagascar, South Africa, South East USA, Mexico, Venezuela, Columbia and Eastern South America. Chemical Constituents

The scientific studies have proved a variety of biochemical components i.e. secondary metabolitbes have been found in Centella asiatica. The chemical constituents of Centella plant have a very important role in medicinal and nutraceutical applications and it is believed due to its biologically active components of triterpenes and saponins. The triterpenes of Centella are composed of many compounds including asiatic acid, madecassic acid, asiaticoside, madecassoside, brahmoside, brahminic acid, brahminoside, thankinoside, isothenkinoside, centelloside, madasagic acid, centic acid, and cenellicacid. Among these triterpenes, the most important biologically active compounds are the asiatic acid, madecassic acid, asiaticoside, madacassoside. Due to their importance, they have been used as the biomarker-components for quality assessment of Centella. However, the content of Centella's triterpene components can be affected by the location and diverse environmental conditions. In addition to terpenoids, it also contains high total phenolic contents which contributed by the flavonoids such as quercetin, kaempferol, catechin, rutin, apigenin and naringin and volatile oils such as Caryophyllene, farnesol and elemene. According to Zainol et al. the highest concentration of phytochemicals was found in the leaves relative to the petioles and the roots. Centella is also rich in vitamin C, vitamin B1, vitamin B2, niacin, carotene and vitamin A. The total ash contains chloride, sulphate, phosphate, iron, calcium, magnesium, sodium and potassium.

Functional Properties

Antioxidant activity

Antioxidative properties of essential oils and various extracts from many plants are of great interest in both academics and the food industry, since their possible use as natural additives has emerged from a growing trend to replace synthetic antioxidants by natural ones. Centella asiatica is well known to have a high antioxidant activity. Antioxidant activity of Centella asiatica is comparable to the activity of rosemary and sage and has very good potential to be explored as a source of natural antioxidants. Hashim et al. reported that antioxidant in Centella asiatica is comparable to Vitamin C (89%) and grape seed extract (83%). Wong et al. studied the antioxidant properties of Centella asiatica, expressed as Trolox equivalent antioxidant capacity (TEAC), using DPPH and FRAP assays. They find out a strong correlation between TEAC values obtained for the DPPH assay and...
those for the FRAP assay which implied that compounds in the extracts were capable of scavenging the DPPH free radical and reducing ferric ions. 

Centella asiatica leaves exhibited higher antioxidant activities using boiled aqueous extraction compared to aqueous extract in DPPH and FRAP assays. Total flavonoid content and total phenolic content also respond better in boiled aqueous extraction when compared to aqueous extraction. Gupta and Panikash find out that Centella asiatica cultivated in India showed good antioxidant activity which was assessed by DPPH, reducing power and ferrous ion chelating capacity methods. They also find out that Casia was a good source of antioxidants like ascorbic acid, total and beta carotene and total phenolics. Their regression analysis showed that the relationship between antioxidant activity and antioxidant contents was highly significant. Subhasree et al. also studied the antioxidant contents and antioxidant activity of Centella asiatica cultivated in India. Their results showed that Centella had a good antioxidant activity and good source of antioxidant contents. According to Zainol, et al. among the different parts of C. asiatica, leaves showed highest antioxidant activity which also contains highest phenolic contents, when compare to other plant parts. This result suggests that phenolic compounds are the major contributors to the antioxidant activities of C. asiatica. On the other hand, Abdul-Hamid et al. reported that ethanol extract of root of C. asiatica exhibited the highest activity though it was not significantly different from the leaves. The antioxidant activity of different parts of C. asiatica may be due to the reduction of hydroperoxides, inactivation of free radicals, chelation of metal ions or combinations thereof. Dasgupta and De find out that Centella asiatica has strongest DPPH radical scavenging activity and highest total antioxidant capacity based on gallic acid and ascorbic acid equivalent among the eleven edible Indian green leafy vegetables studied. Centella is a good scavenger of hydroxyl and superoxide radical and also has good lipid peroxidation preventive property. It also has the highest total phenol content and total flavonoid content when compared to other leafy vegetables. According to Odhav et al. Centella asiatica leaves showed higher level of antioxidant activity among the 20 traditional leafy vegetables cultivated in South Africa. Here the antioxidant activity was expressed as % scavenging capacity of the methanolic plant extracts made from the fresh leaves. The activity obtained for flavonoid rutin was taken as 100% (positive control) and other values represented relative activity compared to rutin. Higher level of antioxidant activity was also observed by Nanosombat and Teckchuen and Akula and Odhav in Centella asiatica plants cultivated in Thailand and South Africa respectively. Vimala, et al. reported that Centella leaves were found to have very high antioxidant activity in three different pathways including superoxide free radical scavenging activity (86.4%), inhibition of linoleic acid peroxidation (98.2%) and radical scavenging activity, DPPH (92.7%). Pittella et al. were finding out that aqueous extract of Centella asiatica showed a high antioxidant activity by its ability to scavenge DPPH free radicals. This activity might be due to the presence of phenolic and flavonic constituents detected in the samples. Huda-Faujan et al. studied the total phenolic content and antioxidant activity of methanolic extracts of Centella asiatica by reducing antioxidant power, ferric thiocyanate (FTC) and thiobarbituric acid (TBA) methods. The data of this study also suggested that Centella asiatica may be a potent source of antioxidant due to their high total phenolic content. Huda-Faujan et al. also obtained similar results on the antioxidant activity of Centella asiatica cultivated in Malaysia. Similar studies were also conducted by Jeyamalar and Suhaila and Norham et al. about the antioxidant activity of Centella asiatica cultivated in Malaysia. Ullah et al. studied the n-hexane, carbon tetrachloride and chloroform soluble fractions of methanol extract of the plant Centella asiatica against antioxidant activity. All the fractions showed moderate to potent antioxidant activity, of which the chloroform and aqueous soluble fraction demonstrated the strongest antioxidant activity. Oxygen radical absorbance capacity (ORAC) value of methanolic extract of Centella asiatica was higher than the aqueous methanolic and ethyl acetate extracts of the same plant. Tan et al. find out the solid-to-solvent ratio of 1:1.5 was the optimum condition for extraction of phenolic compounds (TPC and TFC) of C. asiatica by using ethanol as a solvent among the different solid-to-solvent ratio like 1:5, 1:10, 1:1.5 and 1:2.0. This ratio also exhibited higher antioxidant capacities (ABTS and DPPH radical scavenging capacities) when compared to other ratios. Higher level of antioxidant activity was observed in ethanolic extract of Centella leaves when compared to aqueous extract. Gnanapragasam et al. were finding out the protective effect of Centella asiatica on antioxidant tissue defense system against adriamycin induced cardiomyopathy in rats. Co-administration of Centella protects animals from arsenic induced oxidative stress but exhibits no chelating property. Hussain et al. evaluated the effect of Centella asiatica extract and powder in reducing oxidative stress in Spraque Dawley rats. Results of their studies revealed that C. asiatica extract and powder reduced the H2O2-induced oxidative stress by decreasing lipid peroxidation via alteration of the antioxidant defense system of the rats. Veerandra Kumar and Gupta find out that the aqueous extract of whole plant of C. asiatica have two pronounced effects on Male Wister rats, i.e. improving the learning and memory and, the antioxidant property by decreasing the lipid peroxidation and augmenting the endogenous antioxidant enzymes in brain. The findings by Gupta et al. suggest the potential of aqueous extract of C. asiatica as adjuvant to anti-epileptic drugs with an added advantage of preventing cognitive impairment. Similar research findings were also obtained by Shinomol and Muralidara. Oral treatment of crude methanol extract of Centella asiatica on lymphoma-bearing mice significantly increased the antioxidant enzymes, like superoxide dismutase (SOD), catalase and glutathione peroxidase (GSHPx).

Shukla, et al. investigated the role of asiaticoside as antioxidant properties in wound healing activity. Asiaticoside derived from Centella has been attributed to increase the antioxidant levels at an initial stage of healing. Yusuf, et al. also observed the antioxidative activities of carotenoid and ascorbate peroxide in herb Centella. Casiaasiatica exhibited optimum antioxidant activity at neutral pH and the activity remained stable up to 50°C. The antioxidative activities of Centella extracts increased when concentration was increased from 1000 to 5000ppm. Subhan et al. isolated two new flavonoids named castillicifen 1 and castillicetin 2 from the whole plant of Centella asiatica. These isolates exhibited good antioxidant activity with DPPH radical solution. According to Chanwitheesuk et al. Centella asiatica contains higher levels of natural antioxidants compounds like vitamin E, vitamin C, total carotenes, total xanthophylls, tannins and total phenolics and good antioxidant index among the 43 edible plants cultivated in Thailand. 

Antibacterial activity

Various microorganisms are known to cause food spoilage and food borne diseases in human beings. About 200 diseases are caused by contaminated water, milk and other foods. The most frequently identified causal organisms are *Cor nebacterium diphtheriae*, *Escherichia coli*, *Staphylococcus aureus* and *Pseudomonas aeroginosa*. Many plants were found to contain compounds, which are used as natural medicines to treat common bacterial infections. Medicinal plants are regularly used in various system of medicine because of minimal side effect and cost effectiveness. The potential for developing antimicrobials from higher plants appears rewarding as many plant isolates exhibit broad spectrum activity. Darrhea is a major public health problem in developing countries. Multiple drug resistance among enteropathogens in various geographic regions presents a major threat in the control of diarrhoea. Mamtha et al. was observed broad spectrum activity of
Centella asiatica against a wide range of enteric pathogens. They used viable cell count method to study whether the observed inhibition was bactericidal or bacteriostatic in action. In case of Vibrio cholerae, Shigella species and Staphylococcus aureus, the alcoholic extract of plant showed bactericidal action within 2 hours. Ullah et al.\textsuperscript{35} observed the n-hexane, carbon tetrachloride, chloroform soluble fractions of methanol extract from the plant. Centella asiatica showed antibacterial activity against 5 gram positive bacteria (Bacillus cereus, Bacillus megaterium, Bacillus subtilis, Staphylococcus aureus and Sarcina lutea) and 8 gram negative bacteria (Escherichia coli, Pseudomonas aeruginosa, Salmonella paratyphi, Salmonella typhi, Shigella boydii, Shigella dysenteriae, Vibrio mirmicus and Vibrio parahemolyticus).

Wei et al.\textsuperscript{37} was observed that methanol extract of C. asiatica whole plant showed inhibition zone against V. alginolyticus, V. vulnificus and Streptococcus sp while inhibition zone was found in C. freundii and all Vibrio sp. except V. vulnificus against aqueous extracted C. asiatica whole plant.

Taemchua et al.\textsuperscript{39} was found that crude extract of Centella asiatica, particularly extracted with water, had a promising antibacterial effect against Staphylococcus aureus. Water extracts of Centella leaves cultivated in Similipal biosphere reserve in Orissa, India showed antibacterial activity against Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Bacillus subtilis, Shigella flexneri and Candida krusei.\textsuperscript{50}

Methanolic extract of Centella was showed antibacterial activity against 3 Vibrio species named V. harveyi, V. alginolyticus and V. parahaemolyticus. But acetone, chloroform and hexane extracts was not showed antibacterial activity against these species.\textsuperscript{50}

Hexane, dichloromethane, ethyl acetate, diethyl ether and methanol extracts of Centella asiatica showed antibacterial activity against B. subtilis, K. aerogenes, P. vulgaris and S. aureus species. But they did not show antibacterial activity against Escherichia coli and Pseudomonas aerogenous.\textsuperscript{52} Similarly Srivastava et al\textsuperscript{59} and Zaidan et al.\textsuperscript{59} was also observed the antibacterial activity of Centella plant extracts by using diffusion method. Methanolic extract of C. asiatica showed antibacterial activities to gram positive S. aureus and Methicillin Resistant S. aureus (MRSA). But it did not show antibacterial activities to gram negative bacteria like E. coli and K. pneumonia.\textsuperscript{59}

Ethanol extract of Centella asiatica shows significantly higher rate of sensitivity against various bacteria strains like Staphylococcus aureus, Escherichia coli, Bacillus subtilis, and Propionibacterium vulgaris, while petroleum ether extract shows moderately sensitivity and water extract showed that least sensitivity against these strains.\textsuperscript{52} Crude extracts of Centella asiatica showed antibacterial activity against agne inducing bacteria like Propionibacterium acnes and Staphylococcus epidermidis.\textsuperscript{50}

Panthi and Chaudhary\textsuperscript{50} was observed that methanolic extracts of Centella asiatica collected from Nepal showed antibacterial activity against one gram positive bacteria Staphylococcus aureus and three gram-negative bacteria like Escherichia coli, Pseudomonas aeruginosa and Shigella boydii. But another similar study in Nepal by Mahato and Chaudhary\textsuperscript{52} was not observed antibacterial activity in methanolic extracts of Centella asiatica against bacteria like Bacillus subtilis, Staphylococcus aureus, Escherichia coli and Pseudomonas aeruginosa.

Extracts of Casiatica did not showed antibacterial activity against ten isolates of pathogenic fish bacteria including Aeromonas hydrophila, Citrobacter freundii, Edwardsiella tarda, Escherichia coli, Staphylococcus aureus, Streptococcus agalatiae, Streptococcus aginosus, Vibrio alginolyticus, V. parahaemolyticus and V. vulnificus.\textsuperscript{54} Ethanol and ethyl acetate extracts of Casiatica plant leaves cultivated in Thailand did not showed antibacterial activity against some gram positive and negative bacteria like Staphylococcus coagulase positive bacteria (Bacillus cereus, Bacillus megaterium, Bacillus subtilis, Staphylococcus coagulase negative Listeria innocua, Bacillus subtilis, Lactobacillus plantarum, Lactococcus lactis, Proteus mirabilis, Pseudomonas aeruginosa, Escherichia coli and Salmonella anatum).\textsuperscript{54} Water extract of Centella did not show antimicrobial activity against E.coli, Staphylococcus aureus and Klebsiella pneumoniae.\textsuperscript{38}

**Antifungal activity**

Ethanol and petroleum ether extracts of Centella asiatica plant shows significantly higher rate of antifungal activity against various fungal strains like Aspergillus niger, Aspergillus flavus and Candida albicans when compared to water extracts.\textsuperscript{53} Hexane, carbon tetrachloride, chloroform and aqueous soluble fractions of methanolic extract showed antimicrobial activity against various yeast and mold strains like Aspergillus niger, Saccharomyces cerevisiae and Candida albicans.\textsuperscript{55}

Methanolic extract of Centella asiatica showed significant inhibitory effect on spore germination against various fungal strains like Alternaria, Cercospora, Curvularia, Drechslera and Fusarium. The inhibitory effect on spore germination of the above fungus strains was increased proportionately with the increase in the concentration of methanolic extracts of the leaves.\textsuperscript{55-64}

Bobbarala et al.\textsuperscript{67} examined the antifungal activity of forty nine plants including Centella against Aspergillus niger fungi using agar well diffusion method. Among the 49 plants studied the methanolic extracts of 43 plants including Centella exhibited varying degrees of inhibition activity against the above fungi. Methanol, chloroform and acetone extracts of Centella asiatica showed significant inhibitory effect on growth and sporulation of Colletotrichum gloeosporioides.\textsuperscript{65}

Alcoholic extracts of Casiatica did not showed antimicrobial activity against yeasts like Picha anomala and Saccharomyces cerevisiae and molds like Aspergillus niger and Penicillium pinophilum.\textsuperscript{44}

**Antiviral activity**

Crude water extracts of combinations each of Centella and Mangifera indica showed anti-herpes simplex virus activities.\textsuperscript{69}

**Antiprotozoal activity**

Alcoholic extract of entire plant showed antiprotozoal activity against Entamoeba histolytica.\textsuperscript{71}

**Antifilarial activity**

A mixture of ethanolic extracts of Centella asiatica and Acacia auriculiformis resulted in a considerable decrease in filarial counts in dogs naturally infected with Dirofilaria immitis.\textsuperscript{77}

**Antidiabetic activity**

Asiaticoside prevented development of cold induced gastric ulcers in rats. Asisiticoside administered orally to rats, significantly reduced the formation of stress induced ulcers. Extract of the plant inhibited significantly gastric ulceration induced by cold and restraint stress in Charles-Foster rats. The dose dependent reduction of gastric ulceration was associated with a dose dependent increase of the GABA level in the brain.\textsuperscript{72} Fresh juice of the plant showed significant protection against the experimental ulcer models and the ulcer protective effect may be due to strengthening of the mucosal defensive factors.\textsuperscript{72} Results of the studies conducted by Abdullah et al.\textsuperscript{80} also revealed protection of gastric mucosa and inhibition of leukocytes infiltration of gastric wall in rats pretreated with C. asiatica extract.

**Antidiabetic activity**

Ethanol and methanolic extracts of C. asiatica had shown significant protection and lowered the blood glucose levels to normal in glucose tolerance test carried out in the alloxan induced diabetic rats.\textsuperscript{80} Nganlasom et al.\textsuperscript{80} were treated the wounds of the diabetic induced Male Spraque-Dawley rats with Centella plant extract. They found the wounds of the plant extract treated wounds epithelialised faster when compared to control.

**Anti-inflammatory activity**

Extract of Centella exerted anti-inflammatory effects by reduction of acute radiation reaction in rats. Casiatica water extract and its active constituent asiaticoside have an anti-inflammatory property
that is brought about by inhibition of NO synthesis and thus facilitate ulcer healing 77. Crude extract of Centella asiatica showed anti inflammatory activity in rats by prostaglandin E2-induced paw edema. Bioactive terpenic acids such as asiatic acid and madecassoside may be present in the crude extract that may account for the anti inflammatory activities 78.

Cytotoxic and antitumour activity
A partially purified fraction of methanol extract of C. asiatica inhibited the growth of tumour cells with no toxic effects on lymphocytes. Water extract has a chemo preventive effect on colon tumourigenesis 79. Asiatic acid was found to have anticancer effect on skin cancer80. Asiaticosides possesses good wound healing activities because of its stimulative effect on collagen synthesis. It might be useful in cancer chemotherapy as it induces apoptosis and enhances antitumour activity of vincristine in cancer cells8. The n-hexane, carbon tetrachloride, chloriform and aqueous soluble fractions of methanol extract of C. asiatica showed significant cytotoxic activities in the brine shrimp lethality bioassay82.

Neuroprotective activity
The consumption of Centella was useful to protect the cells from oxidative damage, to destroy excess free radicals and keep the oxidative stress state in balance. As a potent antioxidant Centella exerted significant neuroprotective effect and proved efficacious in protecting rat brain against age related oxidative damage. Asiatic acid exerted significant neuroprotective effect on cultured cortical cells by potentiation of the cellular oxidative defense mechanism. Therefore it may prove efficacious in protecting neurons from the oxidative damage caused by exposure to excessive glutamate83. The plant accelerates nerve regeneration upon oral administration and contains multiple active fractions increasing neurite elongation in vitro suggesting that components in Centella may be useful for accelerating repair of damaged neurons 84.

Central administration of colchicine produces marked destruction of hippocampal granule cells and septohippocampal pathways resulting in loss of cholinergic neurons and decreased activities of acetylcholinesterase and choline acetyltransferase. Centella was able to ameliorate the colchicine induced decrease in AChE activity in rats. Thereby prevents colchicine-induced cognitive impairment and associated oxidative stress. Oxidative stress appears to be an early event involved in the pathogenesis of Alzheimer’s disease 85.

It has been reported that Centella asiatica has neuroprotective effect on cognition and hippocampal neurons. During early postnatal development and preventing cognitive deficits, the dendritic arborization of hippocampal neurons is promoted. Prenatal stress is known to adversely affect the learning and memory abilities. Postnatal treatment of Centella asiatica fresh leaves extracts will protect the hippocampal neurons against prenatal stress and also enhanced learning and memory abilities in rats 86.

Cardioprotective activity
Centella asiatica showed cardioprotective effect on antioxidant tissue defense system during Adriamycin induced cardiac damage in rats 87. The alcoholic extract of Centella asiatica whole plant was evaluated by Pragada et al. for cardioprotective activity against ischemia-reperfusion induced myocardial infarction in rats and their results strongly suggests the cardioprotective activity of the plant in limiting ischemia-reperfusion induced myocardial injury.

Skin protective activity
Skin aging appears to be principally related to a decrease in the levels of type I collagen, the primary component of the skin dermis. Asiaticoside, a saponin component isolated from Centella asiatica, has been shown to induce type I collagen synthesis in human dermal fibroblast cells 88.

Radioprotective activity
Centella asiatica could be useful in preventing radiation induced behavioural changes during clinical radiotherapy. The plant extract showed radioprotective properties and pretreatment with it prior to gamma ray irradiation was found to be effective against radiation induced damage in the mouse liver 89.

Immunomodulatory effect
Triterpenoid saponins of Centella showed immunomodulatory effect 90. Pectin isolated from Centella asiatica showed immunostimulating activities 91 and methanol extracts showed preliminary immunomodulatory activities 92. Ethanol extract of Centella asiatica stimulates cell-mediated immune system by increasing neutrophil phagocytic function 93.

Memory enhancing activity
Aqueous extract of C. asiatica showed significant effect on learning and memory enhancing and significantly decreased the levels of norepinephrine, dopamine and 5-HT and their metabolites in the brain. Aqueous extract of the plant showed cognitive enhancing and antioxidant properties in Stereoptozocin induced cognitive impairment and oxidative stress in rats 94. Treatment during postnatal developmental stage with C.asiatica aqueous extract influenced the neuronal morphology and promoted the higher brain function of juvenile and young adult mice 95.

Wound healing effect
Total triterpenoid fraction extracted from C asiatica increased the percentage of collagen in cell layer fibronectin and thus may help in promoting wound healing 96. Asiatic acid and madecassic acid from C.asiatica have demonstrated an increase in peptide hydroxyproline showing an increased remodeling of collagen synthesis in wounds 97. Oral and topical administration of an alcoholic extract increased cellular proliferation and collagen synthesis at the wound site, as evidenced by increase in DNA, protein and collagen content of granulation tissues of rat dermal wounds. Quicker and better maturation and cross linking of collagen was observed in the extract treated rats, as indicated by the high stability of the acid soluble collagen and increase in aldehyde content and tensile strength. The extract treated wounds were found to epithelialise faster and the rate of wound contraction was higher, as compared to control wounds 98.

Asiaticosides enhanced induction of antioxidant levels at an initial stage of healing which may be an important contributory factor in its healing properties 99. Asiaticoside exhibits significant wound healing activity in normal as well as delayed healing models and is the main active constituent of C. asiatica. Asiatic acid and asiaticoside were more active than madecassic acid. Thus the plant appears to be effective in the treatment of wound healing disturbances 100.

CONCLUSION
Centella asiatica has been in use since time immemorial to treat wide range of indications. It has been subjected to quite extensive phytochemical, experimental and clinical investigations. The dynamic nature of indigenous knowledge has led to its survival through centuries. The use of this knowledge is necessary as it is not only socially desirable but is economically affordable, sustainable and involves minimum risks and procedures 101-102. Many research studies have demonstrated its different functional properties like antioxidant activity, antibacterial, antifungal and antiviral activities, antiulcer activity, anti diabetic activity, anti-inflammatory activity, cytotoxic activity, cardio, neuro and skin protective activities, radioprotective activity, immunomodulatory effect, memory enhancing activity and wound healing effect. With a very low toxicity as attested by its long popular use as a natural product, Centella can be a potential herbal plant in many healthcare applications 103-105.

REFERENCES
5. Sharma BL and Kumar A. Biodiversity of medicinal plants of Triyugi Narain (Garwahl Himalaya) and their conservation, National conference on recent trends in spices and medicinal plant research, Calcutta, WB, India, 1998 (2-4 April): A-78


