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Recent Pharmacological Advances of Endangered Species of South India: *Garcinia indica* Choisy

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Authors' contributions

This work was carried out in collaboration between all authors. Author GGK executed experimental work under the guidance of author VAP. Planning of experiments were done by both of them. The review was prepared while writing the M. Tech thesis by author GGK under the guidance of author VAP. Author ND as a dean of the DYP University, Mumbai had research experience on Garcinia spp. hence the editing part of the work was carried out by authors GGK and ND while writing the review. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Garcinia indica Choisy of the family Clusiaceae is a medicinally important polygamodioecious tree. It is widely distributed throughout Asia, Africa and Polynesia. In India it is found in Western Ghats of South India and North Eastern states. All the parts of the tree is being used since ancient times in food preparations and known for its medicinal importance in treating acidity, ulcer, weight loss, inflammation, etc. Hydroxy citric acid and Garcinol are two major phytochemical present in this plant responsible for its various medicinal property and contains a large number of other important phytochemicals. This review provides a summary of the recent pharmacological advances in the past six years using the various *Garcinia indica* plant parts extracts. This pharmacological activity includes cardio protective, antacid, anthelminthic, anti-oxidant, anti-cancer activity, etc. Thus the review provides a background for the hyper-production and isolation of bioactive compounds from this medicinally important plant for treating various ailments. Phytochemical analysis of the aqueous and methanol *in vivo* leaf extracts of *Garcinia indica* C. revealed the presence of many

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phytochemicals. When the total flavonoid content, total tannin content, total phenolic content and total phosphomolbednum reducing capacity was checked, flavanoid concentration in the methanol leaf extracts was more than 35 mg/100 ml which was much higher than the *Garcinia cola* seeds, *Zingiber officinale* stems, *Gongronema latifolia* leaves and *Carica papaya* leaves. Further studies will prove the bioactives responsible for curing different ailments. Hence, *G. indica* will be explored to understand the pathway, action and the compounds/bioactives responsible for different disease curing properties and its isolation and further pharmacological usage.

Keywords: Garcinia indicia choisy; hydroxy-citric acid; garcinol; phytochemicals; anti-oxidant; anti- cancer and cardio protective.

1. INTRODUCTION

Garcinia indica Choisy (Kokam) belonging to family Clusiaceae is an under exploited spice tree. The scientific name Garcinia is derived from Garcias who described it in 1574. It is a slender evergreen and polygamodioecious tree with dropping branches which attains pyramidal shape on maturity [1]. It is found at an altitude of about 800 meters from sea level. The tree grows about 15 to 20 meters in height ranging moderate to large in size [2]. In India, it is mostly found in Konkan region of Maharashtra, Goa, Karnataka, Kerala and Surat district of Gujarat on the West Coast of India and to some extent in the forests of Assam, Meghalaya, West Bengal [1,2].

The tree is known by different names in different languages and states, like it is known as *brintion,* to the Portuguese in Goa, *bhirand or amsol* in Marathi and Konkani, *murgal* in Kannada and *punampuli* in Malayalam [1]. The National Medicinal Plant Board, India, has identified 'Kokum' as one of the 32 prioritized species of plants for promotion and development [3]. It has also now been included under the list of endangered species of medicinal plants of South India [4]. Biotechnological investigations have been initiated way back in 1960 and many papers on repetitive somatic embryogenesis and other aspects have been published from this laboratory too. While working on phytochemical analysis of the leaves of mature female trees and tissue culture studies along with *Agrobacterium rhizogenes* transformation which have been carried out recently, has helped to explore and consider the recently studied pharmacological activities in the past few years for further research.

1.1 Traditional Uses of Kokum Fruits

Kokam has traditionally been known in Ayurveda and used for treating various ailments such as allergic rashes, burns, chaffed skin and scalds; provide relief from sunstroke; tackle dysentery and mucus diarrhea; improve appetite and quench thirst; treat bleeding piles, tumors and heart problems; and as a tonic for the heart and liver. Due to its known traditional use the fruit has widely been studied for treating various diseases. The two major phyto constituent isolated from the fruit of the tree are Hydrocitric acid known to be an anti-obesity agent and garcinol an anti-oxidant [3].

Fig. 1. *Garcinia indica* tree from Konkan area near Mulshi Pune district Maharashtra, India
A: tree with green fruits in March; B: Tree with Red ripe fruits in May; C: Red fruits removed from tree

1.2 Classification of *Garcinia indica* [2,5]

Kingdom: Plantae
Division: Mangoliphyta
Class: Mangoliopsida
Order: Malpighiales
Family: Clusiaceae
Subfamily: Clusiodeae
Tribe: Garcinieae
Genus: *Garcinia*
Species: *indica*

Various parts of the plant are used in food preparations or for its medicinal properties. The

bark is astringent and used for making vinegar [6]. Young leaves are acidic in nature, having components similar to the fruit and used in food preparations [7]. The leaves are also known to have anti-salmonella activity. The seeds of the tree contain fat and are used to make kokum butter, which is proven to have sun protection activity. The oil cake after oil extraction is used as manure. The most widely used plant part is the fruit and the fruit rind known as kokum [8]. The fruit rind is a rich source of phytochemicals, making it medicinally important.

1.3 Composition of Fresh Kokam Rind

Kokam contains about 10% of malic acid, a little tartaric and citric acid [8]. Composition of fresh kokam rind is as follows (Table 1) [9]:

Table 1. Composition of kokum fruit

Nutrient	Amount (%)
Moisture	80
Protein (N × 6.25%)	1.92
Total ash	2.57
Tannins	2.87
Pectin	5.71
Total sugars	4.10
Crude fat	10.00
Anthocyanins	2.40
Crude fiber	14.28
Starch	1.00
Organic acid (as hydroxy citric acid)	22.80

The present review provides the recent pharmacological advances using *Garcinia indica* plant parts. In last six years there has been a tremendous increase in research using extracts from different parts of this plant. Besides its traditional uses, it is found to have potential for treating neurological diseases, provide protection against UV, cardioprotective activity and as antidiabetic agent. It also shows activities such as antimicrobial, anticancer, anti-salmonella, anthelmintic, antiulcer, antacid, anti-ageing, anti-inflammatory and antioxidant [5,10-14].

2. PHARMACOLOGICAL ACTIVITIES

2.1 Antimicrobial Activity

Garcinia indica fruit has been used since ancient times in food preparations and as preservatives. The various phytochemical present in the plant parts have properties to heal various ailments. In order to evaluate such a healing potential of the various plant parts the antimicrobial activity of the extracts was tested against bacterial and fungal species.

Aqueous extract of Garcinia fruit rind showed antimicrobial activity against *Escherichia coli*, *Bacillus subtilis* and *Enterobacter aerogenes* and *Staphylococcus aureus* with minimum inhibitory concentrations of 0.5 mg/ml, 5 mg/ml, 5 mg/ml and 50 mg/l respectively. While the minimum inhibitory concentration against fungal species *Candida albicans* and *Penicillium* sp. was 50 mg/ml [15].

In another study it was found that the different extracts showed varying levels of activity at different concentrations against same organism. An Aqueous extract of the fruit rind gave inhibition zone of 7 mm against *Micrococcus aureus* at 30 µl volume, 9 mm zone against *Bacillus megaterium at 50* µl volumes and 13 mm zone of inhibition against *Pseudomonas aeruginosa* at 100 µl volumes. Similarly, ethanol and methanol extract of the fruit rind gave an inhibition zone of 10 mm against *Micrococcus aureus* at 30 µl volume, 8 mm and 10 mm zone against *Bacillus megaterium at 50* µl volume and 11 mm and 16 mm zone of inhibition against *Pseudomonas aeruginosa* at 100 µl volume [16].

The stem bark crude, flavononlyflavone and proauthocyanin fraction extracts also have antimicrobial activity as confirmed in a study. The crude extract showed good activity against *Staphylococcus aureus*, partial activity against *Escherichia coli* and medium activity against *Salmonella typhi*. Flavononylflavone fraction showed good activity against *Staphylococcus aureus,* no activity against *Escherichia coli* and medium activity against *Salmonella typhi*. While Proauthocyanin showed partial activity against *Staphylococcus aureus*, partial activity against *Escherichia coli* and medium activity against *Salmonella typhi* [11].

The active component responsible for such an activity may be furfural, garcinol or flavononlyflavone and proauthocyanidin as reported [5,10,11]. So, the plant can prove to be a good plant source of antimicrobial agent in the future.

2.2 Anti-salmonella Activity

Salmonella is a common cause of food poisoning and typhoid, especially in the developing countries due to unhygienic conditions, frequent and indiscriminate use of antibiotics leading to

multidrug resistance. Hence antimicrobials derived from plants are gaining more importance. In an investigation by Chand et al. [16] who used aqueous and methanolic extracts of *Garcinia indica* leaves reported the anti- salmonella activity of the plant against three Salmonella species i.e. *Salmonella typhi*, *Salmonella paratyphi* A, and *Salmonella typhimurium*. The aqueous extract of *Garcinia indica* showed activity against all the three Salmonella species with a zone of inhibition of about 25 mm. While the methanolic extract showed zone of inhibition of 22 mm against *S. typhi* and *S. paratyphi* A and a zone of inhibition of 20 mm against *S. typhimurium* . Thus *Garcinia indica* leaf extract can be used to generate novel metabolites and self-medication. Kunder and Parasharami, 2014 also reported the anti-microbial activity of *Garcinia indica* aqueous and ethanol leaf extracts against four pathogenic bacteria species, namely *Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa* and *Agrobacterium rhizogenes* providing the evidence for the non-responsive nature of the leaves to hairy root induction [17].

2.3 Anthelmentic Activity

Helminthiasis is one of the leading causes of production losses specially found in third world countries. Though there are chemical means to control the disease and also through management, increasing resistance of helminthes against anthelmentics had led to the search of new medicinal sources for the development of anthelmintics. Swapna et al used *Garcinia indica* crude extract from petroleum ether, ethyl acetate, methanol and water to test whether the plant exhibits such an activity. Out of these methanol extract, the extract at 50 mg/ml concentration showed the shortest time for paralysis and death of the worms which were fed with the extracts. Even though there was anthelminthic activity the active component responsible for the same is unknown and requires isolation and identification [12].

2.4 Anti-oxidant Agent

Plants are said to produce natural antioxidants that scavenge the free radicals. *Garcinia indica* is one such plant species with good antioxidant activity. This has been confirmed by the phytochemical analysis of the fruit rind extract by Hydroxyl radical-scavenging activity, reducing power activity and Hydrogen peroxide-scavenging activity which yielded results comparable to Ascorbic acid. *Garcinia indica* showed Hydroxyl radical-scavenging activity with about 23.19%-89.02% and Hydrogen peroxide-scavenging activity was about 34.82%-74.96% at concentrations of 10 µg/ml and 500 µg/ml [18].

In order to evaluate the antioxidant and hepatoprotective activity, carbon tetrachloride (1.5 ml/kg) induced liver toxicity in Wistar albino rats was used. The liver protection was measured by using biochemical parameters such as aspartate transaminase (AST), alanine transaminase (ALT), alkaline phosphatase (ALKP) and serum bilirubin (SBRN). The antioxidant effect was determined by using biochemical parameters like sulphoxide dismutase (SOD), glutathione (GSH), lipid peroxidation (LPO) and catalase (CAT). It was found that the extracts showed significant level of antioxidant and hepatoprotective activity at 500 mg/kg dose comparable to standard drug Silymarin (70 mg/Kg) [13].

In another study**,** Albino wistar rats were used to evaluate the anti-hyperlipidemic and antioxidant activity of the fruit extracts. It was found the extracts showed maximum anti-hyperlipidemic activity in cholesterol-oil induced hyperlipidemic rats at a dose of 400 mg/kg/day and also exhibited good antioxidant activity greater than standard [19]. This antioxidant property may be due to garcinol, anthocynanins or hydroxy citric acid or the synergistic effect of all three. Thus the plant can be further explored to understand the pathway, action and the compound responsible for this property, its isolation and pharmacological usage.

2.5 Anti-ageing

Elastin and hyaluronic acid are responsible for maintaining the elasticity, smoothness, moisture and lubrication of the skin. On the other hand elastase and hyaluronidase are the enzymes responsible for the degradation of elastin and hyaluronic acid respectively, leading to sagging, dry and wrinkled skin. Reports suggested plant metabolites having anti-oxidant activity can inhibit hyaluronidase and elastase, so a study was undertaken to check the anti-hyaluronidase and anti-elastase activity of *Garcinia indica* fruit rind methanolic extract. The methanolic extract was fractioned into ethyl acetate and water fractions to check their activity as well. The study suggested that the methanolic extract at a concentration of 750 µg/ml showed 94% hyaluronidase inhibition, while ethyl acetate fraction at a concentration as low as 25 µg/ml

produced inhibition of 83.33%. On the other hand methanolic extract at a concentration 200 µg/ml showed 64.02% elastase inhibition, while water fraction at a concentration 200 µg/ml showed 81.02% inhibition. Thus, this suggests the further exploitation of the water fraction to identify the responsible metabolite and its use in anti-ageing formulations [20].

2.6 Anti-inflammatory

Body's response to injury to avoid the spreading of infectious agents and to eliminate dead cells and tissues is known as inflammation. It occurs in four phases and the severity or the extent of the injury decides the degree of the injury. The phytochemical anthocyanins and polyphones have earlier been proven to show anti-inflammatory activity and are also present in the fruit rinds of *Garcinia indica*. So, a study was undertaken which showed that *Garcinia indica* extract at a concentration of 400 mg/kg and 800 mg/kg significantly inhibited paw edema in carrageenan induced hind paw edema in rats. Also the same concentration inhibited exudate formation and granuloma formation in the cotton pellet induced granuloma in rats. It also revealed that *Garcinia indica* extract at the same concentration attenuated the elevation of ALT, AST, ALP, SGOT and SGPT levels, which are elevated during inflammation, thereby suggesting *Garcinia indica* to be a good anti-inflammatory agent either due to its anti-oxidant activity or due to lysosomal membrane stabilization, it inhibits inflammatory response [14].

2.7 Antacid Activity

Diseases like gastritis, peptic ulceration and gastro-oesophageal reflux disease is characterized by acid formation in the stomach leading to a burning sensation in throat and heart area. Usually balance is maintained between factors causing peptic ulcer disease and the defensive system by the stomach mucosal lining. This balance is carried out by potentiation of the mucosal defence along with reduction of acid secretion and its neutralization, enhancement of antioxidant levels in the stomach, stimulation of gastric mucin synthesis and inhibition of *H. pylori* growth one of the causative factors. *Garcinia indica* fruit rind extract has been known since ancient times as a cure to acidity. On the basis of this knowledge a study was undertaken which proved that aqueous extract of the fruit rind of *Garcinia indica* at a dose of 400 mg/kg and 800 mg/kg exhibited significant and consistent acid neutralization as compared to standard sodium bicarbonate and greater than the water in the artificial stomach model [21].

2.8 Anti-ulcer Agent

Phytochemicals present in *Garcinia indica* has been known to have pharmacological properties and hence was selected in a study to evaluate its anti-ulcer activity. Ulceration affects a large number of people in the world and the underlying factors for the same is stress, smoking, alcohol consumption, nutritional deficiencies and investigation of NSAIDs. A study showed that *Garcinia indica* fruit rind water and ethanol extract had significant anti-ulcer activity. The Gastric lesion was induced in rats using HCl or ethanol while ulcerogenesis was induced using indomethacin. Aqueous *Garcinia indica* fruit rind extract showed 52.94% reduction in the former rats and 36.80% reduction in the latter rats. Ethanolic extracts showed 34.45% reduction in the former rats and 61.62% reduction in the latter rats. The compound responsible for this activity is unknown and requires isolation and pharmacological evaluation [22].

2.9 Cardioprotective Activity

The leading cause of death in both the sexes is myocardial infarction which, is resulting in reduced blood supply to the heart muscles viz. myocardium leading to ischemia i.e. death of myocardial muscle. Due to the many side-effects of synthetic drugs, WHO has recommended the use of the drugs herbal in origin. Fruit rinds of *Garcinia indica* due to its phyto-constituents and its known traditional medicinal use was taken to evaluate its cardio protective activity. The results of a study showed that *Garcinia indica* extract at a dose of 250 mg/kg by weight and 500 mg/kg by weight showed significant reduction in the activities of the biochemical parameters, i.e. LDH, AST, ALT, CK-MB, CPK comparing to isoprenaline hydrochloride induced cardiotoxicity in rats and control rats. Similarly the evaluation of membrane bound enzymes, i.e. ATPase showed reduction in their activity of Ca^{2+} ATPase and Mg^{2+}ATPase and significant increase in $Na^{+}K^{+}$ ATPase at the same concentration. Comparing to control and isoprenaline treated group. The cardio protective effect may be due to the membrane stabilizing properties of *Garcinia indica* and due to its ability to inhibit the formation of free radicals. The actual mechanism is yet to be determined [23].

2.10 UV Protection Activity

Increasing levels of pollution have led to the depletion of ozone layer thereby increasing the risk of exposure to harmful UV radiations. The exposure of these harmful UV radiations has acute, chronic and delayed responses, thus making skin care products essential. Sun blockers containing physical blockers like ZnO and TiO_2 have shown to exhibit the whitening effect. The chemical blockers are unstable with physical agents and organic blockers show narrow range of protection. Thus, the quench to identify a broad spectrum sun-blocker has led to the study of *Garcinia indica* fruit extracts and kokum butter extract. Fruit extracts were prepared using acidified methanol, ethanol and ethyl acetate while kokum butter extracts using ethyl acetate were prepared. An evaluation of the UV protection activity of both the fruit rinds and kokum butter using spectrophotometric method, it has revealed that ethyl acetate fraction of fruit rinds had good UV-A and UV-B absorbance at a concentration of 0.4 mg/ml. Kokum butter showed relatively less UV absorbance in the UV-A region than in the UV-B region. Also an evaluation of SPF was determined by preparing various sunscreen formulations. It was found that at 105% concentration of ethyl acetate fraction it had 2.02 Sun Protection Factor (SPF) in the sunscreen formulation, which was quite good. Since the results of these extracts were better than TiO_2, which was taken as a standard, it suggests that this promises to be a good and effective candidate of sunscreen products [24].

2.11 Anti-hyperglycemic Agent

There is a rapid increase in the human population suffering from Diabetes mellitus which would eventually lead to an epidemic of diabetes. This is a disease characterized by lack or resistance to insulin. Even though there is a great advancement in managing diabetes, still disease related complications keep on increasing [25]. The major cause of type 2 Diabetes is oxidative stress, which is controlled by Glutathione (GSH) a thiol. Reduction in GSH leads to many complications like neurodegeneration, myocardial infarction and other cardiovascular issues [26]. *Garcinia indica* has long been known to possess antioxidant and free radical scavenging properties. These are the properties which make this plant an anti-hyperglycemic agent. In a research carried out on euglycemic and streptozotocin (STZ) induced hyperglycaemic Wistar rats of either sex, it was found that the blood glucose level reduced significantly after administration of 400mg/kg of aqueous whole fruit extract. The histopathological studies of the pancreas showed mild congestion with mild decrease in number of islets of Langherhans with a normal beta cell population, indicating the significant amount of recovery as compared to STZ induced hyperglycemia Wistar rats [25]. In another study it was found that aqueous extracts of *Garcinia indica* fruit improved the body weight, reduced the blood glucose level and increased the erythrocyte GSH levels significantly in streptozotocin-induced type 2 diabetic rats [26]. So, *Garcinia indica* can prove to be a potential anti-hyperglycemic agent along with GSH restoration preventing complications.

2.12 Protective Effect against Parkinson's Disease

Parkinson's is a neurodegenerative disorder characterized by tremor, rigidity, bradykinesia, and postural instability. *Garcinia indica* is known for its antioxidant and anti-inflammatory properties. Reports also suggest antispasmodic properties of the extracts. Due to these known properties the methanolic extract of the *Garcinia indica* fruit rind (GIM) was tested for the protective effect in dopaminergic neuronal loss induced by 6-hydroxydopamine (6-OHDA) in a rat model of Parkinson's disease. In the treatment of the 6-OHDA rat model with GIM extracts of various concentrations it was found that it had a neuroprotective effect against 6-OHDA in various behavioral models biochemical models. The Behavioral model showed that with the increased dose of GIM (100, 200, and 400 mg/kg) it showed dose-dependent decrease in the number of rotations, increased the number of steps, decreased the initiation time, restoration of the postural balance and decreased disengage time as compared to 6-OHDA group. Whereas biochemical model revealed reduction in striatum dopamine (DA) and its metabolites 3,4-dihydroxyphenylacetic acid (DOPAC) and homovanillic acid (HVA) comparing to increase in 6-OHDA models. Though the report showed a significant neuroprotective effect the exact mechanism is yet to be determined [27].

2.13 Treatment for Newly Acquired or Recently Reactivated Traumatic Memories

The understanding of cellular and molecular mechanisms underlying the consolidation and reconsolidation of traumatic fear memories has

been enhanced in the recent years because of the extensive studies carried out to elucidate its mechanism. One of the mechanisms found to be instrumental in the consolidation and reconsolidation is the regulation of chromatin structure and function. Histone Acetyltransferase (HAT) activity has been implicated in hippocampal dependent memory. The increase in H3 acetylation in the lateral amygdala, which is a locus of storage of fear memories has shown to be correlated with the enhancement in the long term memory, playing a role in consolidation and reconsolidation of traumatic fear memories. A naturally produced substance, garcinol obtained from the rind of *Garcinia indica* is an inhibitor of HAT. This is shown to impair HAT impairing the long term memory. Also, when garcinol was administered systemically or intra- lateral amygdala within a narrow window, it interfered with the consolidation and reconsolidation and also with the associated neural plasticity in the lateral amygdala. Local infusion in the lateral amygdala showed to impair the H3 acetylation by HAT [28].

2.14 Anticancer Agent

Garcinia indica fruit is being consumed traditionally and is known to have anti-oxidative, anti-inflammatory, anti-angiogenic, and proapoptotic activities. It is because of this activity that recent investigations have proved that the plant also possess anti-carcinogenic property. The major plant component responsible for this is Garcinol. *In vitro* as well as some *in vivo* studies have shown the potential of this compound against several cancers types including Human Breast Cancer Cells, Prostate and Pancreatic Cancer Cells [29,30].

2.14.1 Human breast cancer cells

A study was undertaken to identify the carcinogenic role of cyclin D3 known to be involved in breast tumorgenesis induced by nicotine and the role of Nicotinic Acetylcholine Receptor (nAchR) binding in the regulation of cyclin D3. It was found that cyclin D3 is expressed at high levels in breast cancer cells as compared to normal surrounding cells. Also 9α-nAChR over expression resulted in induction of cyclin D3 while its down regulation reduced cyclin D3 levels. The study also proved that 1μM Garcinol extracted from fruits of *Garcinia indica* inhibited the cell proliferation by down regulating 9α-AChR and cyclin D3. Thus Garcinol plays role in human breast cancer cell proliferation attenuation [31].

2.14.2 Prostate and pancreatic cancer cells

Garcinol a poly isoprenylated benzophenone isolated from *Garcinia indica* fruit rind has potent antioxidant properties. The same component is known to possess anticancer properties causing apoptosis in cancer cells. It was proved in a study that garcinol inhibited cell growth of all the cell lines tested with induction of apoptosis in a dose-dependent manner. The mechanism by which this takes place was found to be down-regulation of NF-kappa B signalling because garcinol inhibited constitutive levels of NF-beta B activity, which was consistent with down-regulation of NF-beta B-regulated genes [32]. In another study garcinol was tested against human pancreatic cell lines BxPC-3 and Panc-1, and it was found that it inhibited cell proliferation and induced apoptosis in the same manner as mentioned earlier i.e, by regulation of NF-kappa B signalling. Thus, it plays a role in prostate and pancreatic cancer [29]. It was also proved in another study that garcinol from *Garcinia indicia* and curcumin from *Curcuma longa* had a synergistic effect enhancing bioactivity and reducing the dose requirement which is higher when administered individually [33].

An exclusive study was undertaken to understand the mechanism of action by which garcinol exhibits anticancer activity which revealed that it targets signal transducer and activator transcription-3 (STAT-3) signalling inhibiting total as well as phosphorylated STAT-3. It was also found to inhibit cell invasion by inhibiting IL-6 induced STAT-3 phosphorylation and production of urokinase-type plasminogen activator, vascular endothelial growth factor and matrix metalloproteinase-9 [34].

Although this is a promising molecule in terms of its anticancer properties, investigations in relevant animal models, and subsequent human trials are warranted in order to fully appreciate and confirm its chemo preventative and/or therapeutic potential.

2.15 Recent Studies

Phytochemical analysis of the aqueous and methanol *in vivo* leaf extracts of *Garcinia indica* C. revealed the presence of many phytochemicals. When the total flavonoid content, total tannin content, total phenolic content and total phosphomolybdenum reducing capacity was evaluated the results obtained were as follows (Fig. 2).

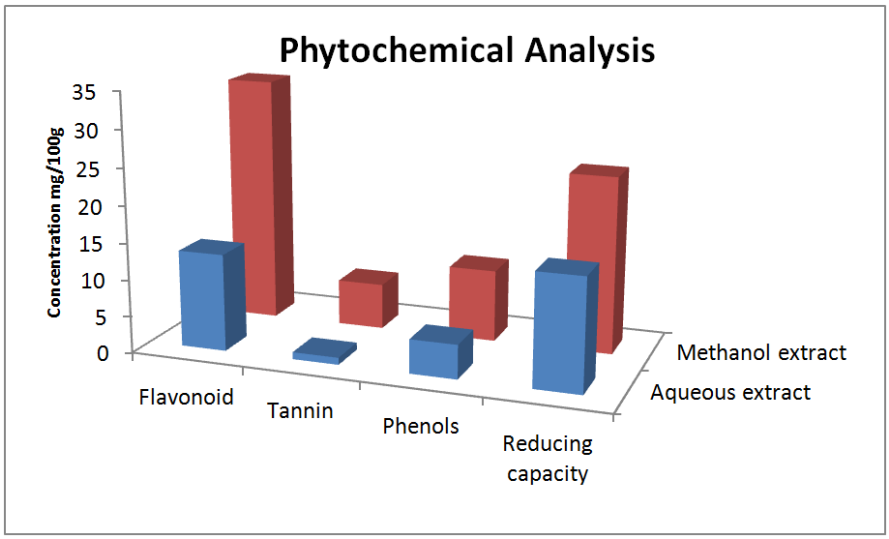

Fig. 2. Comparative graph of phytochemical analysis

It evidently indicated the presence of all the three phytochemicals and its anti-oxidant activity with higher concentration and activity in methanolic extracts. When compared to earlier reports it was found that *Garcinia indica* aqueous *in vivo* leaf extracts had higher concentrations of flavonoids than compared to *Azadirachta indica* leaves, *Garcinia cola* seeds and *Zingiber officinale* stem aqueous and ethanol extract. On the other hand *G. indica* methanol *in vivo* leaf extracts had higher flavonoid content compared to *Azadirachta indica* leaves, *Garcinia cola* seeds, *Zingiber officinale* stem, *Gongronema latifolia* leaves and *Carica papaya* leaves. While tannin content was higher in *G. indica* aqueous and methanol *in vivo* leaf extracts compared to *Azadirachta indica* leaves, *Garcinia cola seeds, Zingiber officinale stems, Gongronema latifolia leaves and Carica papaya leaves* [35]. Also the total phenolic content in *G. indica* aqueous and methanol *in vivo* leaf extracts was higher than *G. indica* methanol *in vivo* fruit extracts [21]. The presence of flavonoids and tannins indicates it has the potential to exert anti-microbial activities, against allergies, against inflammation, in cancer prevention etc. [36-39]. Anti-oxidant activity on the other hand shows its importance in food and research [40].

3. CONCLUSION

The review provides the usefulness and effectiveness of *Garcinia indica* Choisy for treatment of various diseases. This is an addition to earlier reviews up till last six years. All the studies reported in the review are studies on the rat model or just a proof that the plant can be used to treat the said disease. The exact mechanism by which it shows the activity, identification and isolation of the active compound and study *in-vivo* is yet to be accomplished. Till now *in vitro* studies for regeneration through somatic embryogenesis and organogenesis of *Garcinia indica* plant have been done [41,42] but callus and suspension culture studies and the presence of these bioactive compounds in *in vitro* grown cell and suspension cultures have not been reported yet. Hence, if Garcinol, Hydroxy citric acid or any other bioactive compound could be isolated and hyper produced in a cell and suspension culture, it may add value for future research for pharmacological usefulness of *Garcinia indica* Choisy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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