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Review

Terminalia chebula - A pharmacognistic account

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Herbal medicines are in great demand in the developed as well as developing countries for primary heath care because of their wide biological and medicinal activities, higher safety margin and lower costs. *Terminalia chebula* Retz. is an important medicinal plant and has been extensively used in ayurveda, unani and homoeopathic medicine and has become cynosure of modern medicine. It is called "King of Medicines" in Tibet and is always listed first in ayurvedic meteria medica because of its extraordinary power of healing. It has been reported to exhibit a variety of biological activities including, antidiabetic, antimutagenic, antibacterial, antifungal and antiviral activities. All these activities are due to presence of various phytochemicals in plants. Thus, phytochemical analysis of plant is necessary and provides useful information. This review gives a bird's eye view, mainly on the biological and pharmacological activities of some compounds of *T. chebula*, clinical studies and plausible medicinal applications, along with their safety evaluation.

Key words: *Terminalia chebula* Retz., biological and pharmacological activities, plausible medicinal applications, safety evaluation.

INTRODUCTION

Excessive free radical production due to environmental pollution, harmful ultraviolet (UV) radiation and toxic chemicals poses a tremendous threat to our body cells causing disease states such as cancer, atherosclerosis, arthritis, diabetes, dermatological system disorders, cataract and other age related diseases of man (Valko et al., 2007). Some of reactive oxygen species which cause dreadful diseases in human body are hydroxyl radical ($^{\cdot}OH$), superoxide anion ($O_2\cdot^-$), hydrogen peroxide (H_2O_2), singlet oxygen ($^1O_2$) etc. To protect the cells and organ systems of the body against these reactive oxygen species, a highly sophisticated and complex antioxidant protection system are present. It involves a variety of components, both endogenous and exogenous in origin, that function interactively and synergistically to neutralize free radicals. Plants are the potent source of many bioactive compounds such as phenolics, flavonoides, which have free radical scavenging properties and promoted as 'Magic Bullets' for optimum health (Cai et al., 2003). The history of the use of medicinal plants for alleviation of diseases has its origin in primitive times. Though natural product chemistry is an age old science yet it is brimming with fresh potential in the current century with many reports on plants. Several plants are being used in ayurvedic medicines and their medicinal values have been documented in ancient Indian literature. One of the important plants among these in ayurveda is *Terminalia chebula* which is known to be rich in tannins, vitamin C, gallic acid, ellagic acid, anthraquinones, triterpenoids and other miscellaneous compounds (Juang et al., 2004). The various extracts of *T. chebula* has been reported to show a broad spectrum antibacterial, antifungal, antimutagenic, antiviral and antioxidant activities (Inamdar and Rajarama, 1954; Trease and Evans, 1983; Kurokawa et al., 1995; El-Mekkawy et al., 1995; Dutta et al., 1998; Kaur et al., 1998; Jagtap and Karkera, 1999; Malckzadeh et al., 2001; Suguna et al., 2002; Sandip, 2003; Vonshak et al.,

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2003; Walia et al., 2011). According to Indian mythology, this plant originates from the drops of ambrosia (Amrita), which fell on the earth when Indra was drinking it. The fruits are the most important part used in the ayurvedic formulation. The fruits come in the class of Myrobalan, which is a symbol of “Creative power of thought” and are elixir of long life which in high levels of meditative praxis can materialize the unseen worlds in the manner of the myrobalan berry concretised upon the palm of the hand. Thus, this sublime fruit is not just a medicine, but in its materialization by the will of the Buddha upon his hand, it represents blessings from unseen realms, like the healing energy radiating upon devotees in their worship. In this review, an attempt has been made to review briefly the different compounds present in this plant which are responsible for its bioactivities.

Natural distribution

T. chebula occurs naturally from the sub-Himalayan region of Nepal and Northern India to Sri Lanka, Myanmar, Thailand, Indo-China and Southern China (Saleem et al., 2001; Kusirisin et al., 2009; Li et al., 2011) In India, this tree is found in sub-Himalayan tracks form Ravi eastwards to West Bengal, Assam, ascending up to an altitude of 1500 m in the Himalayas. This tree is wild in the forests of Northern India, Uttar Pradesh, Bengal, Madras, Tamil Nadu, Karnataka, Mysore and Southern Maharastra.

Taxonomy and nomenclature

Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Order: Myrtales
Family: Combretaceae
Genus: *Terminalia*
Species: *Terminalia chebula*

Morphological description

T. chebula is a flowering, evergreen, heart gladdening and strength-bestowing tree which attain a height of 30 m, with a trunk up to 1 m diameter and widely spreading branches and a brown roundish crown. Its fragrance spreads to infinite distances and its brightness illumines the earth and sky. The leaves are alternate to sub-opposite in arrangement, oval, 7 to 18 cm long and 4.5 to 10 cm broad with a 1 to 3 cm petiole, elliptical, oblong, with an acute tip, cordate at the base, margins entire, glabrous above with a yellowish pubescence below (Deb, 2006). The flowers are monoecious, dull white to yellow, with a strong unpleasant odour, borne in terminal spikes or short panicles. The fruits are drupe-like, 2 to 4.5 cm long and 1.2 to 2.5 cm broad, blackish, with five longitudinal ridges, glabrous, ellipsoid to ovoid and yellow to orange brown in colour (Aneja and Joshi, 2009). It is capable of growing in different range of soils. The plant flourishes well in areas with an annual rainfall between 100 to 150 cm and a temperature range from 0 to 17°C.

Medicinal value

The plant is described as an astringent, digestive, antiseptic, alternative, laxative, diuretic and carminative (Hartwell, 1982; Singh, 1990; Barthakur and Arnold, 1991). It is also used for blood purification, heal wound and peptic ulcers, diabetes, chronic fever, hypertensions, heart problem, jaundice, vesical and renal calculi, epilepsy, leprosy, ascites, diarrhoea, vomiting, dysentery, cough and dyspnoea. It is also a part of wonder drug “Triphla” which is composite mixture of *T. chebula*, *Terminalia bellerica* and *Emblica officinalis*, a traditional medicine used for the treatment of many chronic diseases such as aging, heart ailments and hepatic diseases (Burapadaja and Bunchoo, 1995; Jagetia et al., 2004; Srikumar et al., 2005). The various extracts of *T. chebula* has been reported to show a broad spectrum antibacterial, antifungal, antimutagenic and antiviral activities (Inamdar and Rajarama, 1954; Trease and Evans, 1983; Kurokawa et al., 1995; El-Mekkawy et al., 1995; Dutta et al., 1998; Kaur et al., 1998; Jagtap and Karkera, 1999; Malckzadeh et al., 2001; Suguna et al., 2002; Sandip, 2003; Vonshak et al., 2003; Bonjar, 2004).

CHEMICAL CONSTITUENTS

T. chebula is known to be rich in tannins, gallic acid, ellagic acid, anthraquinones, triterpenoids and other miscellaneous compounds.

Tannins

Tannins are among the array of chemical compounds that are widely distributed in the plant kingdom and belong to the phenolic class of secondary metabolites. Tannins are oligomeric compounds having multiple structural units with free phenolic groups having molecular weight ranging from 500 to 3000 daltons. Amongst the few families of dicotyledons, particularly Combretaceae is a rich source of tannins. *T. chebula* belongs to the family Combretaceae and is an important medicinal tree, which contains hydrolysable tannins (Han et al., 2006; Kaur et al., 1998). Maximum amount of it is present in the fruit pulp and dried pericarp of the seed

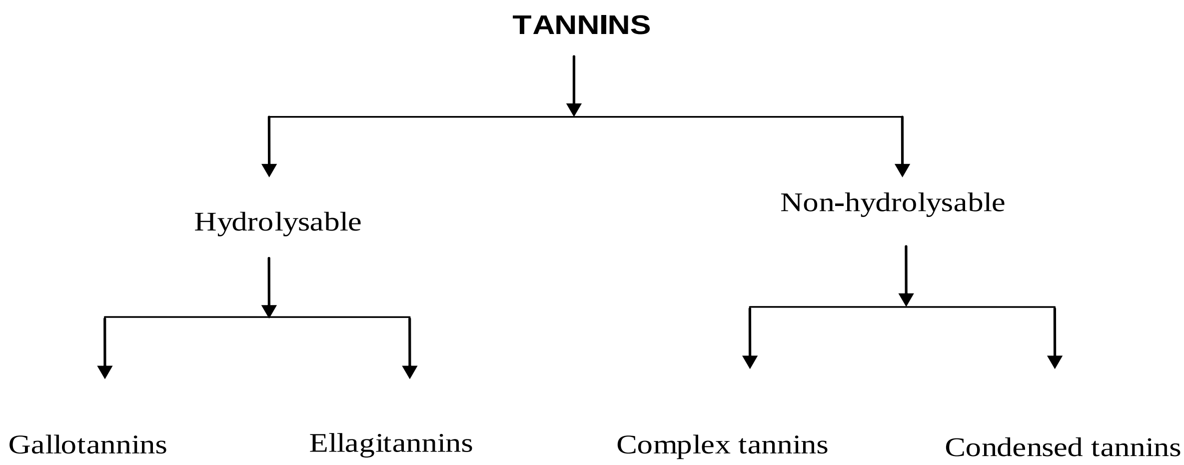

Figure 1. Classification of tannins.

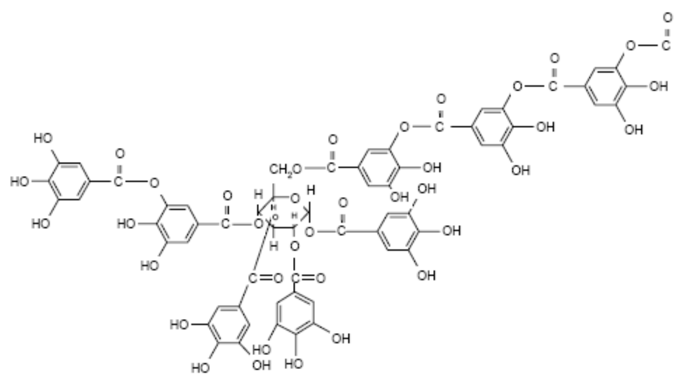

Figure 2. A hydrolysable tannin with a glucose core.

that contains 30 to 35% of tannins (Chadha, 1989; Khare, 2004). Tannins are classified into two broad group viz. hydrolysable and condensed tannins (Haslam, 1996). The observation that many tannins can be fractionated hydrolytically into their components, by treatment with hot water or with tannases, led to the classification of such tannins as “hydrolysable tannins”. Non-hydrolysable oligomeric and polymeric proanthocyanidins were classified as condensed and complex tannins. The main classification of tannins is shown in Figure 1.

Hydrolysable tannins

Hydrolysable tannins contain a central core of polyhydric alcohol such as glucose and hydroxyl groups which are esterified either partially or wholly by gallic acid (gallotannins) or hexahydroxydiphenic acid (ellagitannins, Figure 2).

Hydrolysable tannins are present in many plant species but are found in high concentrations in nutgalls of *Rhus semialata, Quercus infectoria*, seed pods of *Caesalpinia spinosa* and fruits of *T. chebula.* As their name infers, hydrolyzable tannins are readily degraded into smaller molecules. The hydrolysable tannins are subdivided into the gallotannins and ellagitannins.

Gallotannins: Gallotannins are all those tannins in which galloyl units or their *meta*-depsidic derivatives are bound to diverse polyol, catechin or triterpenoid units (Figure 3). Tannic acid is one of the commonly occurring gallotannins in plant kingdom. Gallotannins on hydrolysis by acids or enzymes yields glucose and gallic acid. Lokeswari and Raju (2007) studied the hydrolysis of gallotannins to gallic acid in *T. chebula* by *Aspergillus niger*. Tannase enzyme in *A. niger* convert gallotanins into gallic acid. The results indicate the presence of gallotannis in fruits of *T. chebula*

Ellagitannins: Ellagitannins are produced by the oxidative coupling of galloyl groups in gallotannins. Ellagitannins are those tannins in which at least two

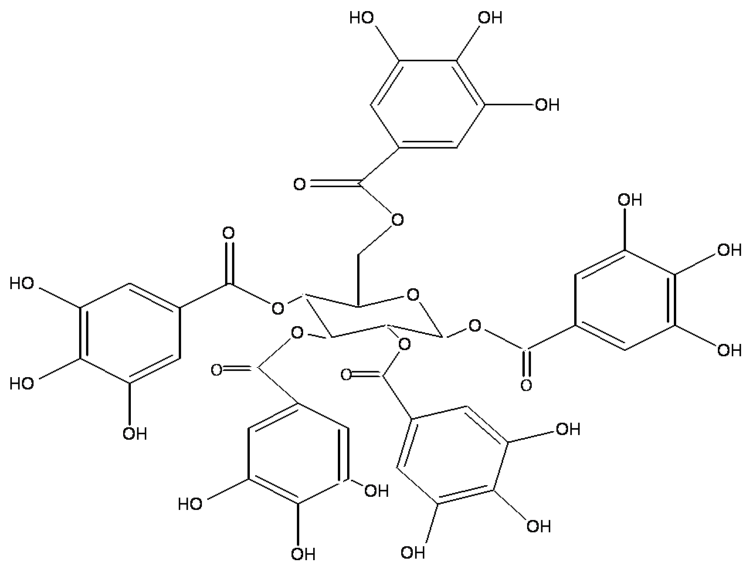

Figure 3. Gallotannin.

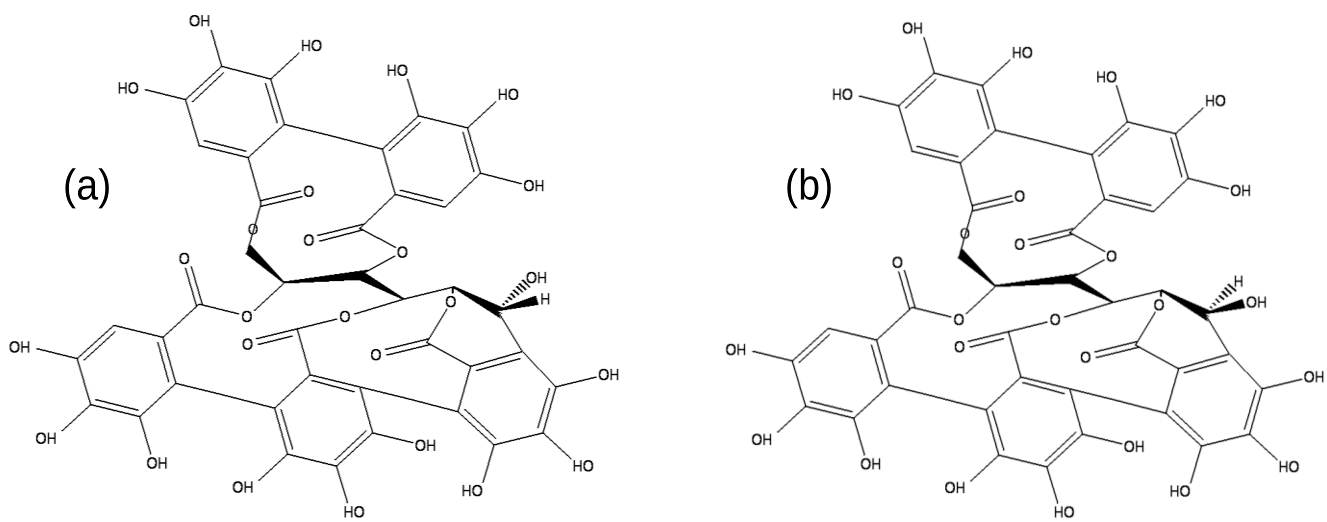

Figure 4. Common ellagitannins. (a), Vescalagin; (b), castalagin.

galloyl units are C–C coupled to each other and are characterized by biaryl-coupled gallic acid moieties esterified to a D-glucose core. They are the esters of hexahydroxydiphenoyl group with sugar core mainly glucose and often contain galloyl groups. The common examples are vescalagin (Figure 4a) and castalagin (Figure 4b). They are widely distributed in *Terminalia* species (Yoshida et al., 2010). Pfundstein et al. (2010) isolated two important ellagitanins that is, 4-*O*-(4″-*O*-galloyl-α-L-rhamnopyranosyl) ellagic acid and 4-*O*-(3″,4″-di-*O*-galloyl-α-L-rhamnopyranosyl from *T. bellerica*, *T. chebula* and *Terminalia horrida.* On hydrolysis, the ellagitannins yields glucose, gallic acid and ellagic acid.

Non-hydrolysable tannins

The second primary class of tannins is non-hydrolysable tannins. These tannins are polymers of primarily flavan-3-ols along with the anthocyanin pigments (Figure 5). If an anthocyanin is incorporated into the tannin, the resulting polymer is often colored. As a covalent bond is formed between the individual units within condensed tannin, these tannins are not readily hydrolyzed. Typically, the linkage occurs between the 4^{th} position (on the heterocyclic ring) and the 8^{th} position on the aromatic A ring, although it is possible for the linkage to occur at the 6^{th} position as well. It is of two types that is, complex and

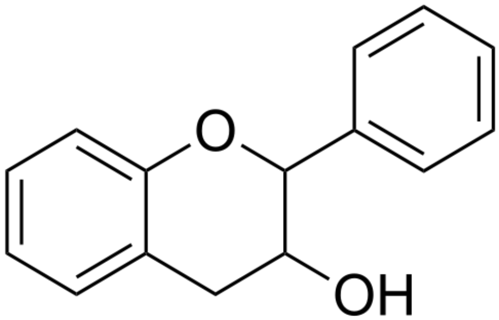

Figure 5. Flavan-3-ols.

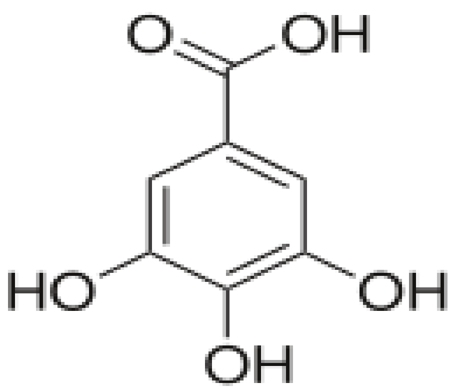

Figure 6. Gallic acid.

condensed tannins. So far, non-hydrolysable tannins are not reported in *T. chebula*.

Gallic acid

Gallic acid is a colorless crystalline organic acid, also known as 3,4,5-trihydroxybenzoic acid found in gallnuts, sumac, witch hazel, tea leaves, oak bark and other plants (Figure 6). Gallic acid is found both in its free state and as a part of tannin molecule. It has two functional groups in the same molecule, hydroxyl groups and a carboxylic acid group which can react with one another to form an ester that is, digallic acid. It is obtained by the hydrolysis of tannic acid with sulfuric acid. When heated above 220°C, gallic acid loses carbon dioxide to form pyrogallol (1, 2, 3-trihydroxybenzene) which is used in the production of azo dyes and photographic developers and in laboratories for absorbing oxygen.

Kaur et al. (1998) isolated gallic acid from dried fruit pulp of *T. chebula* extracting with 95% ethyl alcohol and ethyl acetate. The antimuatagenic activity of gallic acid fraction was evaluated by using Ames assay. This fraction showed moderate activity in this assay. In a subsequent study, Bajpai et al. (2005) isolated gallic acid from the fruits of *T. chebula*. They assessed total phenolic contents and antioxidant activity of some food and medicinal plants. The leaves, bark and fruits of *T. chebula*, *T. bellerica*, *Terminalia arjuna* and *Terminalia muelleri*, the leaves and fruits of *Phyllanthus emblica* andthe seeds of *Syzygium cumini* were found to have high total phenolic content and high antioxidant activity. Banerjee et al. (2005) yielded gallic acid and tannase from fruit powder of *T. chebula* by using filamentous fungi that is, *Rhizopus oryzae* and *Aspergillus foetidus* in co-culture method. Through this method the maximum yield of tannase and gallic acid was found to be 41.3 U/ml and 94.8%, respectively. In continuing research, Rangsriwong et al. (2009) isolated gallic acid, ellagic acid and corilagin from *T. chebula.* They studied the effect of temperature on the extraction of the compounds. It was observed that at 180°C temperature in hot extraction method the extraction of gallic acid was maximum. Likewise, Tubtimdee and Shotipruk (2011) isolated gallic acid from *T. chebula* by employing sugar solution to induce phase separation which resulted in increase gallic acid extraction.

Chebulic acid

T. chebula is known as chebulic myroblan because of the presence of chebulic acid (Figure 7a) and its isomer (Figure 7b). It is important plant phytochemical which commonly occur in gallnuts of combretaceae and euphorbiaceae family. It is also known as 'Long life elixir'. It has a bitter taste and used in various diseases like chronic diarrhoea, dysentery, rectal prolapse, hematochezia, leucorrhoea, night sweating and involuntary emission etc.

Lee et al. (2007) isolated hepatoprotective compound from the ethanolic extract of the fruits of *T. chebula* by consecutive solvent partitioning. The purified compound was identified as a mixture of chebulic acid and its minor isomer, neochebulic acid with a ratio of 2:1. This compound exhibited *in vitro* free radical scavenging activity and ferric reducing antioxidant activity. Using isolated rat hepatocyte experiment it was demonstrated that the treatment of hepatocytes with chebulic acid significantly reduced the tert-butyl hydroperoxide induced cell cytotoxicity and intracellular reactive oxygen species level. By continuing their research, Lee et al. (2010) also reported the anti-hyperglycemic and antidiabtic effect of chebulic acid isolated from *T. chebula*. Chebulic acid significantly reduces the effect of reactive oxygen species in a dose dependent manner.

Chebulagic acid

Its molecular formula is $C_{41}H_{30}O_{27}$ belongs to the class of ellagitannins and it is commonly found in chebulic myroblan

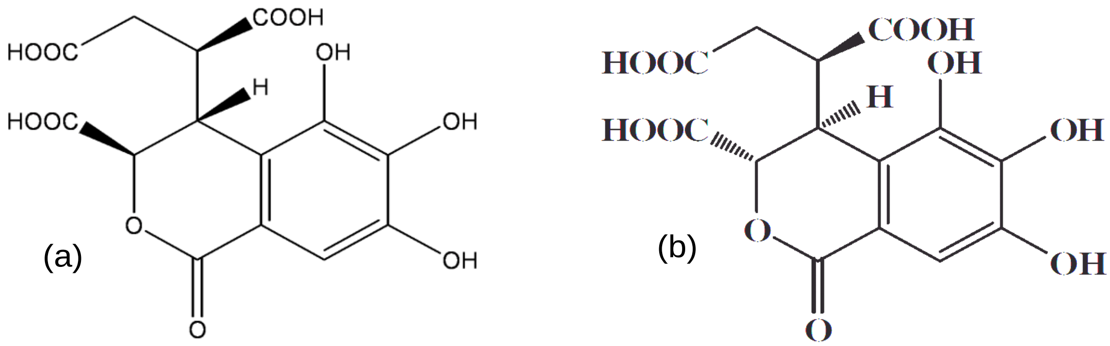

Figure 7. (a). Chebulic acid; (b), neo-chebulic acid.

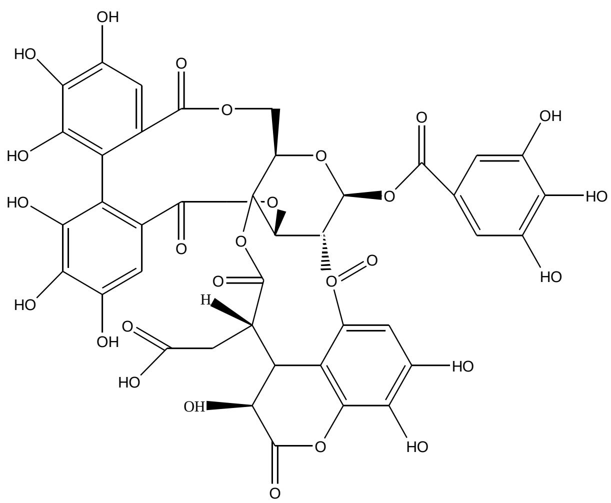

Figure 8. Chebulagic acid.

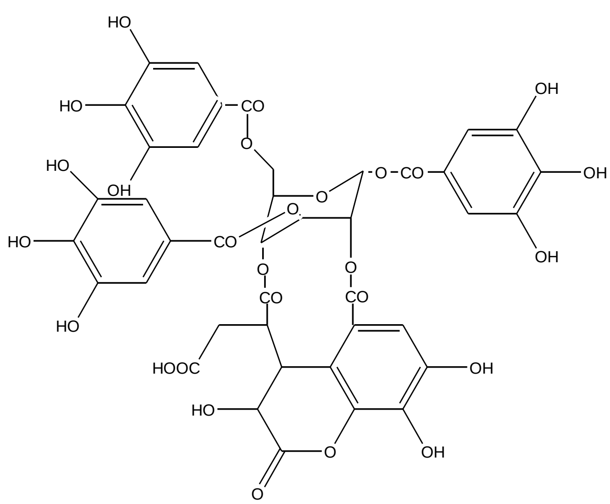

Figure 9. Chebulinic acid.

myroblans (Figure 8). It commonly occurs in seed pods, bark and wood, fruits and leaves or galls of plants belonging to the family Leguminosae, Fabaceae, Combretaceae, Euphorbiaceae and Anacardiaceae. *T. chebula*, which is used as an ancient hepatoprotective drug is rich in chebulagic acid.

Hamada et al. (1997) isolated chebulagic acid and gallic acid from fruits of *T. chebula* as active compounds that blocked the cytotoxic T lymphocyte (CTL) mediated cytotoxicity. Gallic acid and chebulagic acid inhibited the killing activity of CD^{8+} CTL clone at IC_{50} values of 30 and 50 µM, respectively. Granule exocytosis in response to anti-CD_3 stimulation was also blocked by the compounds at the equivalent concentrations. Similarly, Gao et al. (2007) investigated mammalian α-glucosidase inhibitory activity of *T. chebula* Retz. fruits. Using bioassay guided separation, three active ellagitannins were identified as chebulanin, chebulagic acid and chebulinic acid and were shown to possess potent intestinal maltase inhibitory activity with the half maximal inhibitory concentration (IC_{50}) values of 690, 97 and 36 Mm, respectively. Likewise, Lee et al. (2005) examined the effectiveness of chebulagic acid from *T. chebula* against the onset and progression of collagen induced arthritis (CIA) in mice. The results suggested that the chebulagic acid significantly suppressed the onset and progression of CIA in mice. Reddy et al. (2009) evaluated enzyme inhibition activity of chebulagic acid from fruits of *T. chebula* of COX–LOX. The compound significantly inhibited the enzyme activity and also showed good anti-proliferative activity.

Chebulinic acid

It is also known as 1, 3, 6-Tri-*O*-galloyl-2, 4-chebuloyl-*β*-D-glucopyranoside. It is an ellagitannin belonging to the class of hydrolysable tannins, which is widely present in several medicinal plants such as *P. emblica*, *Terminalia arborea* and *T. chebula*.

The molecular structure of chebulinic acid possesses a glucose core that is linked to three galloyl groups and one chebuloyl group. It has acidic nature because of one carboxyl group in chebuloyl group. Its molecular formula is $C_{41}H_{32}O_{27}$ (Figure 9). Saleem et al. (2002) isolated

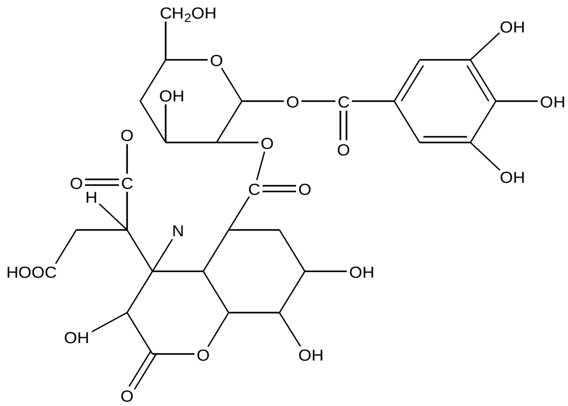

Figure 10. Chebulanin

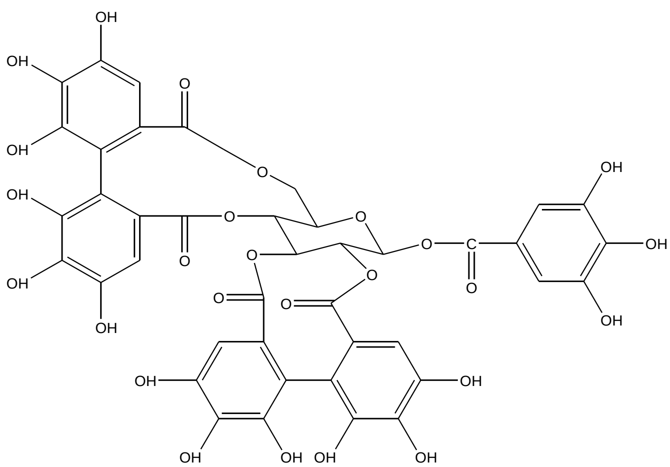

Figure 11. Chebulaginic acid

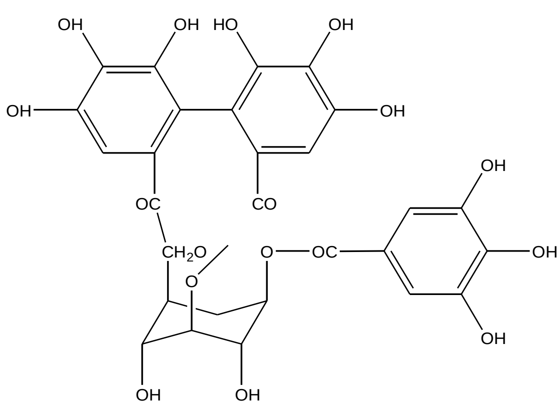

Figure 12. Corilagin

chebulinic acid, ellagic acid, tannic acid and other phenolic derivatives from fruits of *T. chebula* and assessed the anticancer effect.

Chebulanin

The structure of chebulanin is same as that of chebulinic except glloyl core, which is absent in this (Figure 10).

Cheng et al. (2003) isolated 4 pure compounds from fruits of Terminalia chebula namely casuarinin, chebulin, chebulinic acid and 1, 6-di-O-galloyl-β-D-glucose. In this study, 6 extracts and pure compounds of Terminalia chebula were assessed for anti lipid peroxidation, anti superoxide radical formation and free radical scavenging activities. The results showed that all tested extracts and pure compounds of Terminalia chebula exhibited antioxidant activity at different magnitudes of potency. Chebulin showed highest activity in lipid peroxidation assay. Furthermore Gao et al. (2007) isolated three active ellagitannins viz. chebulanin, chebulagic acid and chebulinic acid from fruits of T. chebula and investigated mammalian α-glucosidase inhibitory activity. All the isolated compounds were shown to possess potent intestinal maltase inhibitory activity with the IC50 values of 690 μM, 97 μM and 36 μM, respectively.

Chebulaginic acid

It is widely distributed in plants and mainly found in fruits of family combretaceae and euphorbiaceae (Figure 11). It is an important constituent of fruits of *T. chebula, T. belerica* and *Emblica officinalis* (Han et al., 2006).

Corilagin

It was first isolated in 1951 from Caesalpinia coriaria, which is an important Chinese ayurvedic plant. Its chemical formula is $C_{27}H_{22}O_{18}$ that is an important ellagitanin and mainly found in plants of combretaceae and euphorbiaceae family (Figure 12). Corilagin (β-1-O-galloyl-3, 6-(R)-hexahydroxydiphenoyl-D-glucose) is water soluble polyphenolic tannin has galloxyl and hexahydroxydiphenoyl groups.

Gao et al. (2007) also isolated corilagin from fruits of T. chebula. Likewise Rangsriwong et al. (2009) isolated corilagin, gallic acid and ellagic acid from Terminalia chebula. They studied the effect of temperature on the extraction of the compounds. It was observed that at 120°C temperature in hot extraction method the extraction of corilagin was maximum.

Ellagic acid

Ellagic Acid is a naturally occurring polyphenolic constituent found in 46 different fruits and nuts like pomegranates, red raspberries, strawberries, blueberries and walnuts that has very strong antioxidant properties. Red raspberries are the main source of ellagic acid.

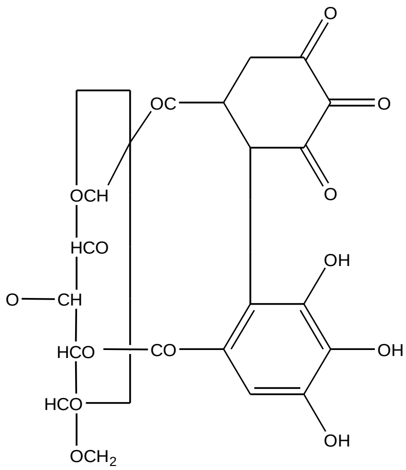

Figure 14. Terchebin

Ellagic acid itself is not thought to be naturally present in plants. Instead polymers of gallic acid and hexahydroxydipenoyl (HHDP) are linked to glucose centers to form the class of compounds known as ellagitannins. When two gallic acid groups become linked side by side within a tannin molecule an HHDP group is formed. Ellagic acid is formed when the HHDP group is cleaved from the tannin molecule and spontaneously rearranges. It is the ellagitannins that are present in red raspberries and its chemical formula is $C_{14}H_6O_8$ (Figure 13). Ellagic acid is a potent anticarcinogen as it acts as a scavenger to "bind" cancer causing chemicals and making them inactive. It is considered to be a cancer inhibitor that has the ability to cause apoptosis or normal cell death in cancer cells. It also has the ability to inhibit mutations within a cell's DNA. In addition to that it has antioxidant, antibacterial, antifungal and antiviral properties. Saleem et al. (2002) isolated ellagic acid chebulinic acid, tannic acid and other phenolic derivatives from fruits of Terminalia chebula and assessed the anticancer effect. In all cell lines studied the extract decreased cell viability, inhibited cell proliferation and induced cell death in a dose dependent manner. Ellagic acid showed highest activity in all assays. The Similar findings has been demonstrated by Naik et al. (2004) who isolated ellagic acid and gallic acid from the fruits of T. chebula and evaluated its antioxidant activity in various invitro assays. The results concluded that the aqueous extract of Terminalia chebula acts as a potent antioxidant and rich in ellagic and gallic acid. Pfundstein et al. (2010) isolated two important ellagitanins i.e. 4-O-(4″-O-galloyl-α-L-rhamnopyranosyl) ellagic acid and 4-O-(3″,4″-di-O-galloyl-α-L-rhamnopyranosyl from Terminalia bellerica, Terminalia chebula and Terminalia horrida. On hydrolysis, the ellagitannins yields ellagic acid, gallic acid and glucose and ellagic acid exhibited potent antioxidant activity. Rangsriwong et al. (2009) also isolated ellagic acid, corilagin and gallic acid from Terminalia chebula. They studied the effect of temperature on the extraction of the compounds.

It was observed that at 180°C temperature in hot extraction method the extraction of ellagic acid was maximum. Likewise, Tubtimdee and Shotipruk (2011) isolated ellagic acid from T. chebula by employing sugar solution to induce phase separation which resulted in increase ellagic acid extraction.

Anthraquinone glycosides

Glycosides are certain molecules in which a sugar part known as the glycone is bound to some other part known as non-sugar group or aglycone by O-glycosidic bond or S-glycosidic bond. The glycone can consist of monosaccharide or oligosaccharide. Many plants store important chemicals in the form of inactive glycosides. When these chemicals are needed, the glycosides are brought in contact with water and an enzyme and the sugar part is broken off, making the chemical available for use. Many such plant glycosides are used as medications. Anthraquinone glycosides are one of them that contain an aglycone group that is a derivative of anthraquinone. They are widely present in Terminalia, Senna, Rhubara and Aloe species. The pericarp of the Terminalia chebula fruit contains anthraquinone glycosides, which are responsible for the laxative effect. Shah et al. (2003) isolated anthraquinone glycoside from Terminalia chebula. They developed spectrofluorimetric method for estimation of total anthraquinone glycoside. The method was based on the reduction of anthraquinone glycoside with sodium dithionite solution in presence of phosphate buffer, which shows strong fluorescence in sodium borate solution having excitation and emission wavelength 385 and 495 nm respectively.

Terchebin

Terchebin belongs to the class of tannins, which is present in the fruits of Terminalia chebula (Jagetia et al., 2002; Ma et al., 2010; Khan et al., 2011). Its chemical formula is $C_{41}H_{30}O_{26}$ (1, 3, 6-trigalloyl glucose, Figure 14). Till now no activity of the terchebin is reported.

Miscellaneous compounds

In addition to the above chemical constituents of Terminalia chebula there are some other compounds that are also present and contribute one or the other way towards the activity of plant. Some of these compounds are palmitic, stearic, oleic, linoleic and arachidic acids are present in fruit kernels.

Palmitic acid: Palmitic acid or hexadecanoic acid is one

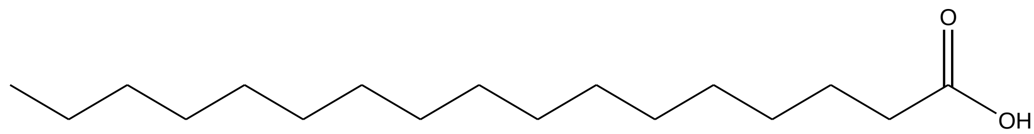

Figure15. Palmitic acid

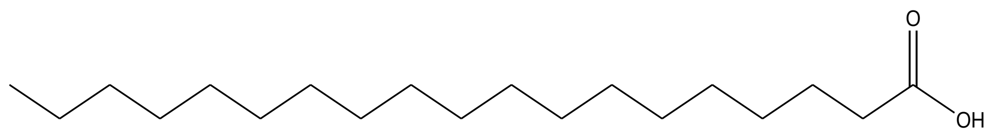

Figure 16. Stearic acid

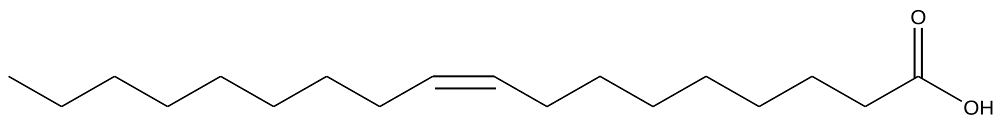

Figure 17. Oleic acid

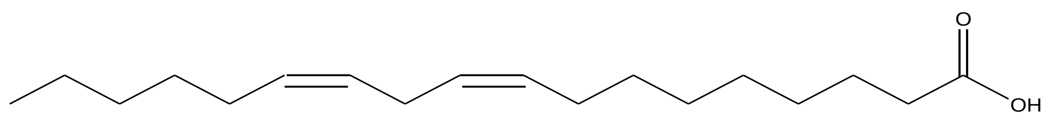

Figure 18. Linoleic acid

of the most common saturated fatty acids found in animals and a plant which is a 16 carbon saturated fatty acid (Figure 15). Its chemical formula is $CH_3(CH_2)_{14}COOH$. Palmitic acid is the first fatty acid produced during lipogenesis (fatty acid synthesis) and from which longer fatty acids can be produced. As its name indicates, it is a major component of the oil from palm trees (palm oil and palm kernel oil. It is abundantly found in fruits of Terminalia chebula (Zhang et al., 1997).

Stearic acid: Stearic acid or octadecanoic acid is one of the useful types of 18 carbon saturated fatty acids that come from many animal and vegetable fats and oils (Figure 16). It is a waxy solid and its chemical formula is $CH_3(CH_2)_{16}COOH$. Stearic acid occurs primarily as a mixed triglyceride or fat with other long chain acids and as an ester of a fatty alcohol. It is much more abundant in animal fat than in vegetable fat. It is present in the seeds of Terminalia chebula (Hosamani, 1994).

Oleic acid: Oleic acid is a monounsaturated omega-9 fatty acid found in various animal and vegetable sources. It has the formula $C_{18}H_{34}O_2$ and saturated form of this acid is stearic acid (Figure 17). It is called a mono-unsaturated fatty acid because of the single double bond between the carbons. Oleic acid occurs naturally in greater quantities than any other fatty acid.

It is present as glycerides in most fats and oils. High concentrations of oleic acid can lower blood levels of cholesterol. It is used in the food industry to make synthetic butters and cheeses. It is also used to flavor baked goods, candy, ice cream and sodas. The olive tree is a major source of oleic acid. Zhang et al. (1997) and Naik et al. (2010) reported the presence of oleic acid in fruits of Terminalia chebula.

Linoleic acid: Linoleic acid is an unsaturated omega-6 fatty acid and chemically it is a carboxylic acid with an 18 carbon chain and two cis double bonds. The first double bond is located at the sixth carbon from the omega end (Figure 18).

Its chemical formula is $C_{18}H_{32}O_2$. Linoleic acid is a member of the group of essential fatty acids because they cannot be synthesized by the human body and must be eaten in food and they are an essential dietary requirement for all mammals. It also repoted in the fruits of Terminalia chebula (Zhang et al., 1997).

Arachidic acid: Arachidic acid which is also called eicosanoic acid is a saturated fatty acid found in peanut

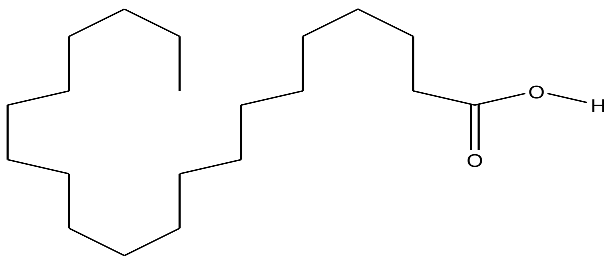

Figure 19. Arachidic acid

oil. It can be formed by the hydrogenation of arachidonic acid. It is a 20 carbon chain fatty acid and its chemical formula is $C_{20}H_{40}O_2$ (Figure 19). It is also found in fruits of T. chebula (Reddy et al., 2009).

Conclusion

This review supports the proposal that Terminalia chebula, a known medicinal plant may be a good source of natural antioxidants and chemopreventive agent. The presence of high levels of phenolic and polyphenolic compounds in the plant may have partly contributed to the observed pharmacological activities. However *in vitro* studies are beneficial to further understand the mechanism of action of this plant as an antioxidant and anticarcinogen. In view of the diversity of methods used for antioxidative and anticarcinogenic evaluation, there is a great need to standardize the *in vitro* methods. The search for more specific assays that give us chemical information, which could be related directly to oxidative deterioration of foods and biological systems, should be the objective of future research. Modern consumers ask for natural products free of synthetic additives. Therefore, the application of natural antioxidants will probably continue in the future and it will be necessary to study their changes and interactions in more details. Plant extracts, their mixtures, isolates and concentrates with antioxidant effects and chemopreventive agents have to meet all the requirements of human health safety.

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