A Review on Thrombolysis Enhancing Indian Edible Plants

Vartika Jain¹, Bhavika Kunwar¹ and S. K. Verma²*

¹Department of Botany, Government Meera Girls’ College, Udaipur, Rajasthan, India.
²Department of Medicine, Pacific Medical College and Hospitals, Udaipur-313001, Rajasthan, India.
*Corresponding Author E-mail: skvermaster@gmail.com

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Impaired thrombolysis is one of the causes of the development of cardiovascular diseases (CVD). The synthetic thrombolytic agents such as streptokinase, urokinase and antistreplase have their own side effects. Plants are always considered as safe and cost-effective therapeutic agents. Dietary therapeutics is an emerging branch for the prevention and treatment of several ailments. The present article compiles 43 edible plants which have shown in vitro thrombolytic potential and are also employed in the diets of several ethnic communities in India. Among these, Bauhinia purpurea and Baccaurea ramiflora are two plants having more than 70% in vitro clot lysis potential; Coccinia grandis, Curcuma longa, Cyperus rotundus, and Typha domingensis have 50-70% thrombolytic activity; and the rest of the plants have 11-49% thrombolytic activity. These 43 plants also include spices and condiments such as Turmeric, Black pepper, Indian Bayleaf, Coriander and Ginger, which affirms the traditional saying of using food as medicine. Besides, these edible plants also possess various phyto-constituents and health-beneficial pharmacological activities. If these plants could be incorporated into a routine diet, it might be possible to prevent or delay the onset of CVD. However, detailed studies are required to evaluate the pattern of CVD in ethnic communities consuming such plants, as well as systematic clinical trials are warranted to investigate the thrombolytic efficacy of these plants.

Keywords: Bauhinia purpurea; Cardiovascular Disease; Food; Streptokinase; Traditional Medicine; Turmeric.

Plants are nature’s wonderful gift to mankind, not only for providing oxygen as one of the most essential requirements of human existence but also for providing food, fodder, fiber, fuel, medicine, dye, timber, etc. Primitive people lived in forests and used natural resources for survival. They realized the importance of various plant species available in the surroundings and started using those species to fulfill the needs of daily life. They also noticed that plants can also act as medicine for prevention and cure of many diseases and ailments and therefore, included several plants in diets. The study of such man-plant relationships forms the discipline of Ethnobotany.

Several edible plants play a very important role in the lives of ethnic communities as they not only provide fresh food but also useful sources of nutrients, medicines, firewood, dyes, building materials, and help in generating income. Moreover, cultivation of edible plants...
also helps in the conservation of many wild plants which are under pressure due to various biodiversity threats. Therefore, a number of studies have been carried out in various parts of the world to document the ethnobotanical knowledge associated with wild edible plant species. Interestingly, many such plant species have demonstrated significant pharmacological activities in animal and human studies, such as antioxidant, anti-inflammatory, analgesic, antimicrobial, hypoglycemic, hepatoprotective, anticonvulsant, anti-platelet aggregation, adaptogenic, immunomodulatory, hypotensive, hypolipidemic, cytotoxic, anti-proliferative, diuretic, and nootropic. Furthermore, these plants are rich in various phytochemicals such as flavonoids, phenols, tannins, alkaloids, saponins, steroids, etc. The presence of bioactive molecules and pharmacological activities scientifically validate many of the folk medicinal claims for the edible plant species and serve as good evidence to recommend them as functional foods.

Thrombus is the main culprit behind cardio-vascular diseases (CVD), leading towards the development of diseases like stroke, embolism, ischemia, deep vein thrombosis etc. Lysis of thrombus is an important event naturally going on in the body with the help of processes such as fibrinolysis. The mechanism behind thrombolytic action is by activating plasminogen, which forms plasmin. Plasmin thus formed cleaves the fibrin and the clot is finally dissolved. If the body’s natural thrombolysis is reduced or impaired for several reasons, it may have serious consequences. In that case, modern medicine takes the help of synthetic thrombolytic agents such as streptokinase, urokinase, tissue plasminogen activator and/or anistreplase, reteplase, tenecteplase. These agents mainly activate plasminogen to start a cascade of events related to thrombolysis. However, some serious side effects are also associated with these agents, necessitating the need for the development of comparatively safer as well as cost-effective thrombolytic molecules.

The diet-disease relationship has been explored in many scientific studies, and changes in dietary behaviour have been shown to reduce the risk of cardio-metabolic disorders. Dietary modifications to improve various health conditions are now a preferred method of treatment as well as prevention of upcoming diseases. Plants have played an important role in various therapeutic diets, such as, Mediterranean diet and Dietary Approaches to Stop Hypertension (DASH) diet. It is recommended that intake of plants which are easily digestible and have high fiber content could be less stressful for heart during acute stages of heart disease. In view of this, plants have been explored to provide safe, effective, and cheaper thrombolytic molecules. Many plant species have exhibited in vitro thrombolytic potential in scientific studies carried out in different parts of the world. Moreover, some of those studied plants are also used as edibles among Indian ethnic communities. The present paper is to provide an overview of current knowledge on edible plant species that have demonstrated in vitro thrombolytic potential and to provide scope for future research.

**MATERIALS AND METHODS**

For this purpose, first, a listing of plants which have shown in vitro thrombolytic activity was done by screening online databases such as Pubmed, Google Scholar, Research Gate, Science Direct, Taylor and Francis, and Springer Link as well as books and non-impact and non-indexed journals using keywords such as ‘in vitro thrombolysis, clot lysis, plants, herbs’ up to July 2022. Further short-listing of those plants was carried out by using ‘Compendium of Indian Folk Medicine and Ethnobotany’ as a reference book to find out whether those plant parts are consumed in diets of Indian ethnic communities. The resultant plants were categorised into four, i.e., having more than 70%, between 50 and 70%, between 30 and 50%, and less than 30% thrombolytic potential and details are given in Tables 1-4 respectively in which the plants are listed alphabetically by botanical names, along with their families, common names in English, habit, plant part used, percent clot lysis, and the corresponding reference. Updated botanical nomenclature for all the plants was used as available on the website.

**RESULTS AND DISCUSSION**

The present paper provides the botanical names and families of 43 edible plant species along with their in vitro percent clot lysis activity. These
43 plants have been distributed in 33 Angiosperm families and the most dominant family was Asteraceae with four plants, followed by Fabaceae with three plants and two each in the Cucurbitaceae, Solanaceae, Rutaceae, Zingiberaceae, and Araceae families. Rest 26 families represent a single plant species. Seven plants belong to the monocotyledon group and 36 plants belong to the dicotyledon group (Tables 1-4). The highest number of plants is represented as herbs (58.13%) followed by trees (23.25%), shrubs, and climbers (9.3% each) as depicted in Figure 1.

The studies included in this paper have a range of 41 to 86% thrombolytic activity for the positive control, streptokinase, and a two-to-ten percent range of thrombolytic activity of distilled water as a negative control.

Notably, two plants have shown more than 70% thrombolytic potential (Table 1) and four have shown 50-70% thrombolytic potential (Table 2). Twenty-six plants have shown between 30 and 50% in vitro thrombolytic potential (Table 3) and twelve plants have shown less than 30% thrombolytic potential (Table 4).

One plant, namely, *Moringa oleifera* (Fig. 2), has been listed twice in Tables 3 and 4 with different plant parts (leaves and flowers) and counted only once. *M. oleifera* is considered as ‘The Miracle tree’ with its multifarious beneficial activities for human health. Though its leaves and flowers possess moderate thrombolytic potential (between 20 to 42%), but along with many nutritive and therapeutic phytochemicals and other pharmacological activities, this plant could be very

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**Table 1. Edible plants with in vitro thrombolytic potential > 70%**

<table>
<thead>
<tr>
<th>Botanical name &amp; Family</th>
<th>Common name</th>
<th>Habit</th>
<th>Plant part</th>
<th>Percent clot lysis</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Baccaurea ramiflora</em> Lour. (Euphorbiaceae)</td>
<td>Burmese grape</td>
<td>Tree</td>
<td>Seed</td>
<td>88.21</td>
<td>18</td>
</tr>
<tr>
<td><em>Bauhinia purpurea</em> L. (Fabaceae)</td>
<td>Purple butterfly tree</td>
<td>Tree</td>
<td>Leaves</td>
<td>91.02</td>
<td>19</td>
</tr>
</tbody>
</table>

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**Fig. 1. Growth form of Indian edible plants showing in vitro clot lysis**
well recommended for dietary therapeutics in the prevention of cardiovascular diseases52.

**Plants having >70% thrombolytic activity**

Interestingly, ethanolic extract of *Bauhinia purpurea* (Fig. 3) leaves have shown 91.02% clot lysis activity, which was more than the standard drug streptokinase, having 72.83% clot lysis activity (Table 1). Leaves of *B. purpurea* are used as vegetables in Bengal, Bihar, Odisha, Jharkhand, Madhya Pradesh and some North-East states of India6. Leaves have shown presence of flavonoids, quercetin, rutin, apigenin and apigenin 7-O-glucoside along with lupeol (34.48%), stigmasterol (15.63 %), lanosterol (4.15 %), ergosterol (2.82 %), hexadecanoic acid, hexadecenoic acid methyl esters, octadecadienoic acids and octadecatrienoic acid, beta-tocopherol, phytol, and vitamin E acetate53,54 as well as hypoglycemic, anti-diarrhoeal and antimicrobial15 activities. Similarly, aqueous extract of *Baccaurea ramiflora* seeds have shown 88.21% clot lysis, which was more than the standard drug streptokinase, which had 78.98% clot lysis (Table 1).  *B. ramiflora* is a wild edible plant native to north-eastern states such as Meghalaya, Manipur, and Arunachal Pradesh6. It is also used during the holy rituals in the ‘Rathyatra’ procession of Lord Jagannath in Odisha56. The fruits of *B. ramiflora* are rich in vitamin C, protein, and iron54. Seeds have shown presence of Sapidolide A and cytotoxic, analgesic, anti-inflammatory, CNS depressant and anti-diarrheal57-58, antioxidant59, hypolipidemic60 and antimicrobial activities61. Seed oil contains palmitic acid (33.67%), stearic acid (19.38%), arachidic acid (9.38%), oleic acid (24.48%), 11-transeicosenoic acid (12.75%) and a high iodine value of 80.3262. In view of this, seeds of *B. ramiflora* could be included in the diet for nutritional as well as therapeutic benefits.

**Plants having 50-70% thrombolytic activity**

Table 2 shows that there are four plants that have shown more than 50% but less than 70% thrombolytic potential. These are *Coccinia grandis* (Fig. 4), *Curcuma longa*, *Cyperus rotundus* and *Typha domingensis*. Leaves of *C. grandis* have been shown to possess anti-inflammatory, antioxidant, hypoglycemic, hypolipidemic, analgesic, and antipyretic activities with beta-sitosterol as an important phyto-constituent along with phenolic and flavonoid compounds63. These are added advantage to its in vitro thrombolytic effect, which was 57.94% as observed in a study by Sultana et al.20. Methanolic extract of rhizome of *C. longa* has shown 53.32% in vitro clot lysis potential. In view of this and its other activities such as platelet aggregation inhibition, anti-inflammatory, antioxidant activities, it is one of the most useful spices used in Indian cuisines64,65. The active ingredient of Turmeric is Curcumin, which possesses anti-viral and immunomodulatory activities along with other pharmacological activities66. Tuberous roots of *Cyperus rotundus L.* are popularly known as ‘Nagarmotha’ in Western India and are used to treat various ailments by native communities of India. It is also used as an edible in North Bihar, Rajasthan and the Attapadi hills situated in the Western Ghats of India6. Ethanolic extract of its rhizome (200µg/ml) has shown 60% in vitro thrombolytic potential22 which validate the traditional knowledge on its use to treat heart stroke by *Taungya* community in Terai Arc Landscape of India67. Antioxidant, anti-inflammatory, cardioprotective, hypolipidemic,

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**Table 2. Edible plants with in vitro thrombolytic potential between 50-70%**

<table>
<thead>
<tr>
<th>Botanical name &amp; Family</th>
<th>Common name</th>
<th>Habit</th>
<th>Plant part</th>
<th>Percent clot lysis</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Coccinia grandis</em> (L.) Voigt. syn. <em>Coccinia indica</em> Wight. &amp; Arn. (Cucurbitaceae)</td>
<td>Scarlet-fruited Ivy gourd</td>
<td>Climber</td>
<td>Leaf</td>
<td>57.94</td>
<td>20</td>
</tr>
<tr>
<td><em>Curcuma longa</em> L. (Zingiberaceae)</td>
<td>Turmeric</td>
<td>Herb</td>
<td>Rhizome</td>
<td>53.32</td>
<td>21</td>
</tr>
<tr>
<td><em>Cyperus rotundus</em> L. (Cyperaceae)</td>
<td>Common Nut Sedge</td>
<td>Herb</td>
<td>Rhizome</td>
<td>60</td>
<td>22</td>
</tr>
<tr>
<td><em>Typha domingensis</em> Pers. (Typhaceae)</td>
<td>Southern Cattail</td>
<td>Herb</td>
<td>Whole plant</td>
<td>67.16</td>
<td>23</td>
</tr>
</tbody>
</table>
antidiabetic, antiobesity, antiplatelet etc. are some of its other health-beneficial activities, recommending it for dietary intake\textsuperscript{68}. Leaves and shoots of \textit{Typha domingensis} are used for food purpose by \textit{Konda Reddis} of Rampa Agency, East Godavari District, Andhra Pradesh, and the inflorescence is consumed in North-East states of Assam and Arunachal Pradesh\textsuperscript{6}. It has been shown to possess antioxidant, vasodilator, hypolipidemic, bronchodilator, cytotoxic, antimicrobial activities and is rich in vitamin E, nonacosane, piperine, triacontane, \( n \)-hexadecanoic acid, decanoic

Table 3. Edible plants with \textit{in vitro} thrombolytic potential between 30-50% \\

<table>
<thead>
<tr>
<th>Botanical name &amp; Family</th>
<th>Common name</th>
<th>Habit</th>
<th>Plant part</th>
<th>Percent clot lysis</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Acmella paniculata} (Wall. ex DC.) R.K. Jansen syn. \textit{Spilanthes paniculata} Wall. ex DC. (Asteraceae)</td>
<td>Paniel-ded spot flower</td>
<td>Herb</td>
<td>Leaves</td>
<td>42.77</td>
<td>24</td>
</tr>
<tr>
<td>\textit{Anacardium occidentale} L. (Anacardiaceae)</td>
<td>Cashew nut</td>
<td>Tree</td>
<td>Nut</td>
<td>33.79</td>
<td>25</td>
</tr>
<tr>
<td>\textit{Boerhavia diffusa} L. (Nyctaginaceae)</td>
<td>Horse Purslane</td>
<td>Herb</td>
<td>Leaf</td>
<td>38.42</td>
<td>27</td>
</tr>
<tr>
<td>\textit{Brassica oleracea} L. (Brassicaceae)</td>
<td>Cabbage</td>
<td>Herb</td>
<td>Flower</td>
<td>42.75</td>
<td>28</td>
</tr>
<tr>
<td>\textit{Merremia vitifolia} f. (Convolvulaceae)</td>
<td>Horse Raddish</td>
<td>Tree</td>
<td>Leaf</td>
<td>41.4</td>
<td>37</td>
</tr>
<tr>
<td>\textit{Piper nigrum} L. (Piperaceae)</td>
<td>Black Pepper</td>
<td>Climber</td>
<td>Fruit</td>
<td>35.4</td>
<td>38</td>
</tr>
<tr>
<td>\textit{Sesamum indicum} L. (Pedaliaceae)</td>
<td>Sesame</td>
<td>Herb</td>
<td>Seed</td>
<td>32.94</td>
<td>38</td>
</tr>
<tr>
<td>\textit{Spinacia oleracea} L. (Amaranthaceae)</td>
<td>Turkey berry</td>
<td>Herb</td>
<td>Fruit</td>
<td>31.52</td>
<td>42</td>
</tr>
<tr>
<td>\textit{Zingiber officinale} Roscoe (Zingiberaceae)</td>
<td>Ginger</td>
<td>Herb</td>
<td>Rhizome</td>
<td>30.13</td>
<td>44</td>
</tr>
</tbody>
</table>
acid, tetracosane, oleic acid, phytol, sitosterol, naringenin, n-acetoacetyl-deacetylcolchicine and many other phyto-therapeutic compounds.**Spices having thrombolytic activity**

Spices have shown moderate thrombolytic potential such as Clove (*Syzygium aromaticum*), Black pepper (*Piper nigrum*), Ginger (*Zingiber officinale*), Red chilly (*Capsicum frutescens*), Coriander (*Coriandrum sativum*), Indian Bayleaf (*Cinnamomum tamala*) as depicted in Table 3 and 4. Some of these spices have also demonstrated anti-platelet potential, which is an important mechanism of clot lysis. Figure 5 depicts 20 common edible plants having *in vitro* thrombolytic activity out of the 43 scrutinized plant species. These species also possess several therapeutic bioactive compounds. For example, capsaicinoids, flavonoids, carotenoids, steroids, saponins in *Capsicum*; monoterpenes, sesquiterpenes, geraniol, linolol, bornyl acetate, phytosterols, caryophyllene oxide, p-coumaric acid, vanillic acid etc. in *Cinnamomum tamala*; flavonoids, gallic acid, ferulic acid, coumarins, salicylic acid, tartaric acid, maleic acid, arbutin etc. in *Coriandrum sativum*; murrayazolidine, murrayazoline, murrayamine, koenimbine, koenine, mahanimbine, 4-terpineol, tanethol, sesquiterpene longifolene α-pinene etc. in *Nigella sativa*; eugenol, carvacrol, linalool, murraya, koenimbine, koenine, mahanimbine, 4-terpineol, tanethol, sesquiterpene longifolene α-pinene etc. in *Murraya koenigii* (Fig. 6); *p*-cymene, carvacrol, thymohydroquinone, thymohydroquinone, thymohydroquinone, 4-terpineol, tanethol, sesquiterpene longifolene α-pinene etc.

![Fig. 2. Moringa oleifera](image)

<table>
<thead>
<tr>
<th>Botanical name &amp; Family</th>
<th>Common name</th>
<th>Habit</th>
<th>Plant part</th>
<th>Percent clot lysis</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Averrhoa bilimbi L. (Oxalidaceae)</td>
<td>Bilimbi</td>
<td>Tree</td>
<td>Fruit</td>
<td>23.94</td>
<td>45</td>
</tr>
<tr>
<td>Camellia sinensis (L.) O. Kuntze (Theaceae)</td>
<td>Black Tea</td>
<td>Herb</td>
<td>Leaves</td>
<td>11.64</td>
<td>46</td>
</tr>
<tr>
<td>Cinnamomum tamala T. Nees &amp; Eberm. (Lauraceae)</td>
<td>Indian bay leaf</td>
<td>False</td>
<td>Leaves</td>
<td>22.10</td>
<td>21</td>
</tr>
<tr>
<td>Eclipta prostrata (L.) L. (Asteraceae)</td>
<td>False Daisy</td>
<td>Herb</td>
<td>Leaves</td>
<td>15.19</td>
<td>24</td>
</tr>
<tr>
<td>Emilia sonchifolia (L.) DC. ex DC. (Asteraceae)</td>
<td>Red tassel-flower</td>
<td>Beach</td>
<td>Whole plant</td>
<td>22.57</td>
<td>47</td>
</tr>
<tr>
<td>Launaea sarmentosa (Bip. ex Kuntze) (Asteraceae)</td>
<td>Horse Raddish tree</td>
<td>Tree</td>
<td>Flower</td>
<td>20.52</td>
<td>37</td>
</tr>
<tr>
<td>Murraya koenigii Sprin. (Moringaceae)</td>
<td>Curry leaf tree</td>
<td>Tree</td>
<td>Leaves</td>
<td>22.14</td>
<td>40</td>
</tr>
<tr>
<td>Musa sp. var. Nanjangud rasa bale (Musaceae)</td>
<td>Black cumin</td>
<td>Herb</td>
<td>Seeds</td>
<td>18.13</td>
<td>48</td>
</tr>
<tr>
<td>Nigella sativa L. (Ranunculaceae)</td>
<td>Black cumin</td>
<td>Herb</td>
<td>Seeds</td>
<td>28.49</td>
<td>21</td>
</tr>
<tr>
<td>Pistia stratiotes L. (Araceae)</td>
<td>Water lettuce</td>
<td>Herb</td>
<td>Leaves</td>
<td>12.06</td>
<td>49</td>
</tr>
<tr>
<td>Zanthoxylum rhetsa DC. (Rutaceae)</td>
<td>Indian prickly ash</td>
<td>Tree</td>
<td>Leaves</td>
<td>25.23</td>
<td>50</td>
</tr>
</tbody>
</table>
β-caryophyllene, rosmarinic acid, oleanolic acid, ursolic acid etc. in *Ocimum tenuiflorum* (Fig. 7);
gingerol, shoagaol, paradol, quercetin, zingerone, gingerenone-A in *Zingiber officinale* (Fig. 8);

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![Fig. 3. Bauhinia purpurea](image1.png)  ![Fig. 4. Coccinia grandis](image2.png)

**Fig. 3. Bauhinia purpurea**  **Fig. 4. Coccinia grandis**

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![In vitro percent thrombolytic activity graph](image3.png)

**Fig. 5.** Some common edible plants demonstrating *in vitro* thrombolytic activity
Piperine as major constituent in *Piper nigrum* besides volatile oil, oleoresins, and alkaloids; sesamin, sesamol, sesamolin, pinoresinol etc. in *Sesamum indicum* (Fig. 9) and eugenol, eugenyl acetate, β-caryophyllene etc. in *Syzygium aromaticum*⁸⁰. Besides, many pharmacological activities such as antioxidant, anticancer, antidiabetic, anti-inflammatory, immunomodulatory, hepatoprotective, platelet aggregation inhibition, neuro-protective, nephroprotective, and cardio-protective have also been reported from these plants⁸⁻⁷₂. This further emphasizes that use of these plants in the diet could be beneficial for many purposes.

**Thrombolytic activity of leaves of edible plants**

Plant based diets including leafy green vegetables provide strong evidence for benefits in cardiovascular risk factors such as obesity, diabetes, hypertension, high lipid levels etc.⁷³. In the present analysis, leaves of 42% of the plants were consumed and reported to possess thrombolytic activity, followed by fruits (22%), seeds (13.33%), flowers (8.88%), and rhizome and whole plant (6.66% each), which is depicted in Figure 10.

*Spinacia oleracea* is a well-known leafy vegetable that has shown 40.9% thrombolytic potential (Table 3). It is considered a functional food as it is rich in various vitamins and minerals as well as many therapeutic phytochemicals such as flavones, flavanols, glucuronides, methylenedioxyflavonol glucuronides, and carotenoids. Spinach helps in
scavenging reactive oxygen species and thereby prevents macromolecular oxidative damage. It has also been shown to modulate genes which are involved in metabolism, proliferation, inflammation, and antioxidant defense and therefore, demonstrates various pharmacological activities such as antioxidant, hypolipidemic, hypoglycemic, anti-hypertriglyceridemia, anti-obesity, anticancer, anti-inflammatory, anti-amylose, and bileacid binding capacity. In view of this, intake of spinach can help in thrombolysis and also provide protection against several other ailments.

Leaves of *Murraya koenigii*, known as Curry leaf tree is used for flavor in various Indian cuisines and exhibited 22.14% in vitro thrombolytic potential (Table 4). The cardio-protective potential of *Murraya koenigii* has been demonstrated in doxorubicin-induced cardiotoxicity in Wistar albino rats. Lyophilized leaf extract of *M. koenigii* was administered orally in a concentration of 2 g/kg to animals for 14 days, which significantly reduced the levels of cardiac troponin I, NT-pro BNP, aspartate aminotransferase, lactate dehydrogenase, myeloperoxidase along with improvement in reduced glutathione, glutathione reductase, glutathione peroxidase, total antioxidant capacity, superoxide dismutase, and catalase activity, along with a reduction in lipid peroxidation levels. This clearly indicates the cardio-protection ability of *M. koenigii* along with antioxidant and anti-inflammatory activities, and therefore, its daily consumption could be beneficial for the heart. Leaves of *Bacopa monnieri*; a well-known memory-improving plant, have shown 47.39% thrombolytic activity (Table 3). This small herb is rich in several phytochemicals for example, luteolin, quercetin, apigenin, ursoic acid, bacosides, β-sitosterol, stigmasterol, ascorbic acid, bacosapaponins, bacoside, cucurbitacin, wogonin and exhibited various health-beneficial activities such as adaptogenic, antioxidant, antihypertensive, anti-amylose, anti-inflammatory, analgesic, anti-diabetic, anti-arthritic, anti-oxidant, anti-hypertensive, and hepatoprotective. Thus, clot lysis activity is an additional benefit gained by people after consuming its leaves. The leaves of sacred Holy Basil (*Ocimum tenuiflorum*) have also demonstrated anticoagulant properties by prolonging prothrombin time and activated partial thromboplastin time with linolenic acid as a major constituent. The cardio-protective potential of hydroalcoholic extract of *O. tenuiflorum* has also been observed in isoproterenol induced myocardial infarction in rats at a dose of 50 mg/kg further indicating the importance of this herb in CVD.

Leaves of *Emilia sonchifolia* are used to prepare vegetable in western Maharashtra and Nagaland states of India. It is also recommended to treat chest pain by tribal communities in India. Notably, it has demonstrated 28.71% clot lysis activity (Table 4). This plant is rich in flavonoids, flavones glycosides, beta-sitosterol, stigmasterol, ursoic acid, quercetin, quercetin, rutin, kaempferol 3-β-D-galactoside, senkirkine, doronine, n-hexacosanol, and triacontane and has been shown to possess antioxidant, antidiabetic, anti-cataract, anti-inflammatory, antiviral, analogesic and anti-cancer activities. Leaves of *Acmella paniculata* are used for making vegetables in the north-eastern states of India and are mostly used for the treatment of toothache. It is rich in phyto-constituents such as spilanthol, β-sitosterol, stigmasterol, α-and β-amyrin, vanillic acid, llimonene, β-caryophyllene, (z)-β-ocimene, germacrene-D, scopoletin and *trans*-ferulic acid and has also demonstrated anti-inflammatory, antioxidant, vasorelaxant, immunomodulatory, and analgesic activities in animal studies.

*B. oleracea* is another popular vegetable in India. Its flowers and leaves contain phenolics, polyphenols, saponins, tannins, steroids, flavonoids, alkaloids, glucosinolates, reducing sugars, and vitamin C. It has been shown to possess strong antioxidant activity in different antioxidant assays. Moreover, inhibition of DNA methylation, prevention of DNA damage and threats to cancer and cardiovascular diseases are its other benefits. All these bioactive molecules and pharmacological activities make it a good candidate for recommending as a nutraceutical in daily diet. Whole plant of *Launaea sarmentosa* is used as vegetable in Lakshadweep Island and also in Vietnam as nutritious vegetable. It has also shown anti-inflammatory, antioxidant, antidiabetic, and hepatoprotective properties along with 22.57% clot lysis potential.

**Thrombolytic activity of fruits of edible plants**

Out of these 43, fruits from 10 plants are...
used in the diet (Fig. 10). For example, *Anacardium occidentale* (Fig. 11) is one of the famous edible tree nuts. It is consumed as raw, roasted form or also used to prepare sweets in the winter season. Its kernels are rich in protein, vitamin E, K, B6, riboflavin, minerals like potassium, calcium, magnesium, phosphorous, iron, copper, zinc, manganese, selenium etc., glutamic acid, arginine, cholesterol-lowering phytosterols, phosphatidylcholine, beta-sitosterol, lutein, zeaxanthin, epicatechin, catechin, polyphenols, flavanol etc. Cashewnuts have been shown to possess antioxidant, hypoglycemic and hypotensive potential. Thus, the thrombolytic action of *A. occidentale* is an additional weapon for protection from several diseases, including cardiovascular diseases and metabolic syndrome. Pomegranate is another well-known fruit plant which is rich in ellagitannins, polyphenols, luteolin, kaempferol, quercetin, gallic acid, ellagic acid, punicalagin, gallagic acid, delphinidin, cyanidin, pelargonidin, catechin, punicalin, and minerals, such as sodium, potassium, calcium, magnesium, phosphorus, and nitrogen. Fruit and peel of *Punica granatum* have shown anti-thrombotic potential besides anti-inflammatory, anti-diabetic, hypolipidemic, anti-platelet, anticoagulant, cardio-protective and anticancer properties.

Fruits of *Ficus racemosa*, known as ‘Gular’ in India, are rich in nutritive value and full of phytochemicals such as hentriacontane, â-sitosterol, tiglic acid, esters of taraxasterol, lupeol acetate, phytosterol, euphol, euphorbinol, isoeuphorbol, tannins, steroids, tinyatoxin, trimethyl ellagic acid, flavonoids, alkaloids and have demonstrated hypolipidemic, anti-diabetic, anti-carcinogenic, antioxidant, gastroprotective and
analgesic activities in various scientific studies.90 Fruits of *Capparis decidua* (Fig. 12) are used to prepare the famous traditional Rajasthani cuisine ‘Panchkuta’ and are also used to make pickle. Interestingly, a methanolic extract of its fruits has shown a 32.39% clot lysis potential (Table 3). This is an important addition to its pharmacological profile besides anti-atherosclerotic, hypolipidemic, antioxidant, and anti-inflammatory properties.91 Therefore, it could be used in dietary modification for therapeutic benefits.

Fruits of *Solanum torvum* are used as vegetable and also to prepare chutney in eastern India. Ethnic communities of the Mayurbhanj district of Odisha utilize its fruits for the treatment of heart disease.6 Fruits are rich in steroidal glycosides, phenolic compounds, isoflavonoids, etc. Interestingly, its fruits have shown a 31.51% clot lysis potential (Table 3). Besides, thrombolytic potential, fruits of *S. torvum* have also demonstrated anti-inflammatory, antidiabetic, anti-ulcerogenic, anti-hypertensive and anticancer activities in scientific studies.92 Fruits of *Luffa cylindrica* have exhibited 45% clot lysis potential (Table 3) and used as vegetable in Rajasthan, Kerala and Sikkim.6 Its fruits possess vitamin A, B5, B6, C, and dietary fibers as well as phyto-constituents.
such as gallic acid, caffeic acid, cinnamic acid, ferulic acid, ellagic acid, rutin, quercetin, luteolin, robin, vitexin, myricetin, catechin, nootkatone, n-heptacosan, n-hexacosan, n-tetracosan, n-tricosan, etc. Many pharmacological activities have also been demonstrated by fruits of L. cylindrica such as antioxidant, anti-inflammatory, hypoglycemic, antimicrobial, anti-inflammatory, Moreover, it has also demonstrated antioxidant, anti-inflammatory, and sedative which potentiate its use in daily diet\textsuperscript{93}.

Fruits of Averrhoa bilimbi are rich in ascorbic and oxalic acids and possess carbohydrates, proteins, amino acids, coumarin, flavonoids, tannins, essential oils, terpenes, and valepotriates. Besides, many phytochemicals such as hexadecanoic acid, butyl nicotinate, (Z)-9-octadecenoic acid, nonanoic acid, nonanal, (Z)-9-pentacosene, (Z)-3-hexenol, (Z)-9-tricosene, octane, tricosane, (E)-2-decenal, 2-furfural, 2,4-dihydroxy-6-((4-methyl)pentylxyloxy) methyl benzaldehyde etc. have been isolated from its fruits\textsuperscript{94}. Interestingly, anticoagulant activity of ethanol extracts of leaves and fruits of A. bilimbi has been demonstrated in normal and alloxan-induced diabetic rats after oral administration at a dose of 250 mg/kg for 14 days, which has significantly increased prothrombin time\textsuperscript{95}. This further validates the results obtained through in vitro clot lysis activity (Table 4). Seeds of Tribulus terrestris (Fig. 13) are consumed as famine food in Rajasthan\textsuperscript{6} and have shown to possess 33% in vitro thrombolytic activity. T. terrestris possesses various phytochemicals such as quercetin, kaempferol, isorhamnetin, rutin, triluboside, tribulusamid C, tribulusterine, tribulusin A, harmine, benzoic acid, vanillic acid, 2-methyl benzoic acid, and ferulic acid. Moreover, it has also demonstrated antioxidant, hypoglycemic, antimicrobial, anti-inflammatory, cardio-protective, anticancer, anti-aging and hepatoprotective properties\textsuperscript{41,96}.

**Edible plants having thrombolytic and platelet aggregation inhibition activities**

Inhibition of platelet aggregation is another important mechanism for maintaining the patency of blood vessels. Many of the phytoconstituents such as caffeic acid, epigallocatechin, catechin, quercetin, kaempferol, apigenin, gallic acid present in the plants listed in this paper have also shown platelet aggregation inhibition activity\textsuperscript{97}. Likewise, some other compounds, such as Piperin, isolated from Piper nigrum have shown inhibition of platelet aggregation through attenuation of cytosolic phospholipase A\textsubscript{2} and thromboxane A\textsubscript{2} synthase involving arachidonic acid (AA) metabolism\textsuperscript{98}. Curcumin; a polyphenol isolated from Curcuma longa, also demonstrated platelet aggregation inhibition by activating adenosine A\textsubscript{2A} receptor-stimulated protein kinase A activation and phosphorylation of vasodilator-stimulated phosphoprotein\textsuperscript{99}. Gingerol, shogaol, paradol, and gingerol analogues isolated from Zingiber officinale have also demonstrated anti-platelet function\textsuperscript{100}. Similarly, (+)-nootkatone isolated from Cyperus rotundus has also shown significant in vitro collagen-, thrombin-, and AA-induced platelet aggregation inhibition in a dose-dependent manner as well as ex vivo platelet aggregation inhibition in mice blood by increasing tail bleeding time\textsuperscript{101}. Sesamum indicum also possesses many bioactive molecules such as sesamin, episesamin, sesamol, γ-tocopherol, and sesamolin. Among these, epiesamin has shown a strong anti-thrombotic effect by preventing thrombin and activated blood coagulation factor X production, prolonging activated partial thromboplastin time and prothrombin time, reducing thrombin-catalyzed platelet aggregation in mice as well as inhibiting TNFα-induced secretion of plasminogen activator inhibitor type 1 in human umbilical vein endothelial cells\textsuperscript{102}.

Cuscutaroside A and its acetyl derivative, as well as scrophenoside B; isolated from whole plants of Cuscuta reflexa (Fig. 14), have demonstrated a weak platelet aggregation inhibitory activity induced by collagen with IC\textsubscript{50} values of 291.4 ± 47.99 Ig/ml, 63.8 ± 4.4 Ig/ml, and 180.5 ± 6.7 Ig/ml, respectively. However, an acetylated derivative of Cuscutaroside A has shown strong platelet aggregation inhibition induced by AA with an IC\textsubscript{50} value of 72.6 ± 10.5 Ig/ml\textsuperscript{103}. A dose-dependent adenosine diphosphate induced platelet aggregation inhibition has been demonstrated by 70% ethanolic extract of Eclipta prostrata leaves with 74.55%; 65.60%; 48.00% and 39.08% inhibition at the concentration of 100, 80, 60 and 40 mg/ml respectively with an IC\textsubscript{50} value of 59.02 mg/ml\textsuperscript{104}. The mechanism behind the anti-platelet property of E. prostrata and the corresponding bioactive molecules needs to be researched. However, all these studies indirectly support the anti-thrombotic potential of these edible
plant species and provide motivation for initiating further research in this direction.

**COVID-19 treatment potential of edible thrombolytic plants**

Recent pandemic of COVID-19 has hugely affected the human population and thrombotic complications are one of the major causes of morbidity and mortality associated with this infectious viral disease. COVID-19-related coagulation disorders were associated with an increase in D-Dimer, fibrin degradation products, prothrombin time, activated partial thromboplastin time, and a decrease in antithrombin. Interestingly, herbal medicine was also employed to combat this virus and several in vitro, in vivo, and clinical trials have been carried out and are currently underway. Plants like Curcuma longa, Nigella sativa, Zingiber officinale, Piper nigrum, Ocimum tenuiflorum, Cuscuta reflexa, Moringa oleifera, etc. were used in herbal treatment and prevention of COVID-19. Some of the isolated phytochemicals such as quercetin, piperin, curcumin, apigenin, kaempferol, luteolin, thymol, rutin, eugenol, ursolic acid, caffeic acid, and oleancic acid have also shown their potential against the SARS-CoV-2 virus and exhibited anticoagulant activity. In view of their thrombolytic potential, the addition of these plants to the diet for treatment or for prevention purposes seems quite relevant because this has been proven in scientific research related to the efficacy of these plants in COVID-19.

The present article has compiled the Indian edible plants having thrombolytic potential which are commonly used in the diets of various ethnic groups without knowing their multifarious beneficial effects on human health. Theoretically, it is possible to get benefit from these plants in the situation of altered thrombolytic states. In this context, the work of Sarkar is worth quoting, who has advised that few of the plants, for example, Boerhavia diffusa (Fig. 15), Chenopodium album, etc., should be used during the acute stage of heart disease such as acute myocardial infarction. He has stressed that during the acute stage, the diet should preferably include these vegetables. The rationale behind it could be their thrombolytic potential, antioxidant property, anti-platelet and hypolipidemic effect. Moreover, these vegetables are easily digestible without posing undue stress on the heart, which requires rest during the recovery period, and the gut favorable because of high fiber content, which does not allow constipation. Because straining on defecation during this crucial time is also hazardous and can cause arrhythmia and sudden death. Scientific studies have also shown that the intake of dietary fibers can reduce the risk of CVD through various means. For example, a recent cohort study in South Korea has also indicated the role of quality plant food in the prevention of metabolic syndrome. Therefore, dietary selection of plants with the above-mentioned properties could be helpful for management of CVD.

**Safety issues**

Though the edible plants mentioned in this article have thrombolytic activity, they should be consumed with caution. Over-consumption of the plants may cause adverse effects. For example, studies have shown that intake of curcumin in doses of 500-12000 mg produced symptoms like diarrhea, yellow stool, headache, and rashes. Similarly, heartburn, nausea, abdominal pain, gas, bloating, etc. are some of the reported side effects of consumption of Z. officinale (750-2000 mg). Fruits of A. bilimbi can cause nephrotoxicity and neurotoxicity and consumption of 80% fresh plants of T. terrestris has shown harmful effects on cardiac muscle, liver and kidney of goats and sheep. In various animal studies, after consumption of M. oleifera, genotoxicity, kidney and liver damage, necrosis of splenic blood vessels, and neuronal glial cells have been reported. Hepatotoxicity and gastrointestinal disorders after consumption of C. sinensis on empty stomach have been reported. S. oleracea grown in heavy metal polluted sites can create risk for cancer. Likewise, nitrate poisoning has been observed after ingestion of Brassica oleracea var. capitata. Some of these plants such as T. domingensis, B. purpurea, O. tenuiflorum, S. tormum, P. granatum, B. monnieri, and M. koenigii have yet to be tested for significant toxicity. However, plants having higher thrombolytic activity should be recommended cautiously to patients already taking anti-platelet and fibrinolytic enhancing drugs and supplements because there is a possibility of bleeding.
CONCLUSION

The present article provides an overview of 43 plants which have demonstrated thrombolytic potential and are also being utilized by ethnic communities for edible purposes. If these species could be added as a supplement to the diets of people who are predisposed / susceptible to cardiovascular diseases, they may serve the role of preventive agents. Addition of these plant species to the diet, both before and after the development of disease, could be beneficial in myriad ways due to the multifarious therapeutic potential of plants, which mostly act in a synergistic manner. However, large scale clinical studies could be executed for scientific evaluation of the effect of the addition of these plant species in the diet on the prevention or betterment of CVD. In this regard, the two edible plants with the highest clot lysis potential, namely, Baccaurea ramiflora and Bauhinia purpurea, should be screened for their in vivo thrombolytic potential on a priority basis.

Conflict of Interest

Authors declare that there is no conflict of interest.

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