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## Review on potential importance and value added products of *Averrhoa bilimbi* Linn

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### Abstract

Medicinal use of various plant components such as leaves, bark, flowers, fruits, seeds, roots, or the entire plant has a long history in various cultures. *Averrhoa bilimbi*, commonly known as bilimbi, is a folk cure for a variety of medical conditions. It is a attractive, long-lived tropical tree that grows to be 5-10 metres tall. It has a small trunk with several erect branches. Coughs, beri-beri, and biliousness are all treated with the fruit preserve. The fruit's syrup is used to treat fevers and inflammation, as well as to halt rectal bleeding and relieve internal haemorrhoids. On itches, mumps and rheumatic swellings, and skin eruptions, the leaves are administered as a paste or poultice. The leaves contain anti-diabetic and anti-lipidemic properties. Coughs and thrush are claimed to be helped by a flower infusion. *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella enteritidis* are all susceptible to the leaves and fruit extract. This review aims at compiling the potential benefits and value added products of *Averrhoa bilimbi* Linn.

**Keywords:** Potential, value, bilimbi, *Averrhoa bilimbi* Linn

### Introduction

Bioactive chemicals are abundant in plants. They are the primary source of medications that have been utilised as herbal remedies for health care, prevention, and healing of many diseases and disorders since ancient times. (Kalia *et al.*, 2005) Many Indian plants are utilised for their anti-diabetic properties. (Pulok K *et al.*, 2009), antihyperlipidemic activity and antibacterial activities (Patel *et al.*, 2011). *Averrhoa bilimbi* is a popular folk treatment for a variety of ailments. It has antibacterial, antiscorbutic, astringent, and postpartum protecting properties. It's also used to cure fever, mumps, acne, rectum inflammation, diabetes, itches, boils, rheumatism, syphilis, bilious colic, whooping cough, hypertension, stomach discomfort, and ulcer, as well as as a cooling drink. (Saravana Kumar *et al.*, 2011)

*Averrhoa bilimbi* (Oxalidaceae family) is a beautiful, long-lived tropical tree that grows to be 5-10 metres tall and has a small trunk that divides into a number of erect branches. White, soft yet strong, even-grained wood that is rarely accessible for carpentry. The leaves are alternating, imparipinnate, and generally clustered at the branch terminals; 30-60 centimeters long, with 11-37 alternate or sub opposite leaflets, elliptical or oblong, with rounded base and pointed tip, downy, medium-green on the top surface, pale on the underside; 2-10 cm long, 1.2-1.25 centimetres broad. Flowers are tiny, fragrant, auxiliary or alternative type, five petalled, yellowish green or purplish marked with dark-purple, 10-22 mm long, and are distributed in small, hairy panicles that emerge immediately from the trunk, oldest, thickest branches, and certain twigs, as are clusters of peculiar fruits. Fruit is ellipsoid, obovoid, or almost cylindrical, 4-10 cm long, with a thin, star-shaped calyx at the stemend and five hair-like floral remains at the apex. Crispy while unripe, the fruit ripens to a yellowish-green colour, ivory or virtually white colour, and falls to the ground. The flesh is green, jellylike, juicy, and exceedingly acidic, and the outer skin is shiny, very thin, delicate, and soft. A few 6-7 flattened, disc-like seeds, six mm broad, smooth, and brown, may be present. (Saravana Kumar *et al.*, 2011)

*Averrhoa bilimbi* is a tropical tree that is more susceptible to cold, particularly when young. It enjoys direct sunshine and seasonally humid regions with equally distributed rainfall for the majority of the year, although a 2-3 month dry season is required. Bilimbi flourishes on soil that is rich, wet, somewhat acidic, and well-drained. It grows and fruits well on sand or limestone as well. Bilimbi flowers in February and continues to blossom and bear fruit until December.

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### Phytochemicals

Alkaloids, saponins, tannins, flavonoids, phenols, and triterpenoids are some of the phytochemical components found in *Averrhoa bilimbi*. (Hasim YA *et al.*, 2019)<sup>[10]</sup>

#### Alkaloids

Alkaloids are a class of natural chemical compounds made up mostly of basic nitrogen atoms that have neutral, mildly acidic, or amphoteric characteristics. Alkaloids include oxygen (O<sub>2</sub>), sulphur (S), and additional elements such as chlorine (Cl), bromine (Br), and phosphorus (P) in their molecular structure. Alkaloids containing oxygen compounds are frequently crystallised and colourless, whereas oxygen-free alkaloids are usually volatile, colourless, oily liquids in the form of yellow (berberine) or orange (sanguinarine). Alkaloids dissolve easily in organic solvents like 1, 2-dichloroethane, chloroform, or diethyl ether but soluble poorly in water. *Averrhoa bilimbi* leaves contain potassium-alkaloid and potassium tetraiodomercurate complexes, according to phytochemical analysis of alkaloid compounds. (Yanti S *et al.*, 2019)<sup>[11]</sup>. The extract from *Averrhoa bilimbi* leaves macerated in 70% ethanol included alkaloids, generating white sediment in Meyer reagent and reddish-brown sediment in Dragendorf and Wagner reagents. (Andayani R *et al.*, 2014)<sup>[12]</sup>. Alkaloids have pharmacological properties, including anticancer and antiviral properties. (Hasim YA *et al.*, 2019)<sup>[10]</sup>. By intercalating into cell walls and DNA, alkaloids operate as antibacterials. (Andayani R. *et al.*, 2019)<sup>[12]</sup>. Plant alkaloids can decrease the action of dihydrofolate reductase, an enzyme required for pyrimidine synthesis, RNA and DNA manufacture, and hence nucleic acid synthesis. Inhibition of nucleic acid synthesis results in bacteria with underdeveloped DNA cells. (Othman L *et al.*, 2019)<sup>[20]</sup>.

#### Saponins

Saponins are bioorganic compounds with a large molecular weight that are extensively extracted from medicinal plants. (Aziz *et al.*, 2019)<sup>[21]</sup>. A hydrophobic aglycone with 27-30 carbon atoms and one or two hydrophilic sugar units with 6-12 carbon atoms make up this chemical molecule. (Moses T *et al.*, 2014)<sup>[22]</sup>. Saponins are triterpenoid (30 carbon atoms) and steroids in chemical structure (27 carbon atoms with a 6-ring spirostan or a 5-ring furostane skeleton). Saponin content is determined by the plant's tissue type, age, genetic background, physiology, and environmental conditions. (Faial A *et al.*, 2013)<sup>[23]</sup>. The Forth technique is used to examine the saponin chemicals found in the *Averrhoa bilimbi* leaf. The leaf extract produced a steady foam up to 1 cm in height, indicating the presence of saponin (Yanti S *et al.*, 2019)<sup>[11]</sup>. Other studies showed the presence of saponins in *Averrhoa bilimbi* extract by producing foam 1-3 cm after adding hot water and HCl to the test. Saponins are immunomodulators, anticarcinogens, anti-inflammatory, antiviral, antibacterial, antiprotozoal, hypoglycemic, hypocholesterolemic, and antioxidants with pharmacological properties. Saponins and cholesterol metabolism are linked because saponins can lower cholesterol by binding to bile acids in the gut. Saponins can prevent bile acids from being reabsorbed by intestinal cells, causing them to be ejected with faeces. (Saraswati R *et al.*, 2018)<sup>[7]</sup>.

#### Tannins

Tannins are phenolic polymers with molecular weights ranging from 500 to 20,000 Daltons. (Corral MF *et al.*, 2020)<sup>[24]</sup>. Tannins contain a special chemical structure called hydroxyls, which may form a stable cross-linked relationship with other molecules including carbohydrates and proteins. Hydrolysable and condensed compounds are the two primary groups of this chemical (proanthocyanidins) (Othman L *et al.*, 2019)<sup>[20]</sup>. By adding FeCl 35 percent solution to the sample, phytochemical testing of tannin components in the extract of *Averrhoa bilimbi* leaf was performed. (Yanti S *et al.*, 2019)<sup>[11]</sup>. Polyphenols in the sample will form complexes Fe<sup>3+</sup>+ tannins/polyphenols with a coordination bond and change colour. The tannin component in the *Averrhoa bilimbi* leaf extract sample seems to condense, turning blackish-green. The existence of tannin components in *Averrhoa bilimbi* extract has been proven. Tannin is an antibacterial agent that may bind to adhesin, block bacterial enzymes, and form complexes with metal ions. (Andayani R *et al.*, 2014)<sup>[12]</sup>. The tannin antibacterial mechanism of *Averrhoa bilimbi* is carried out with the help of other compounds. Tannin chemicals can swiftly penetrate bacterial cells and target cell wall polypeptides to suppress bacterial cell wall formation once the bacterial wall is lysed or ruptured by saponins and flavonoids. (Rusdianan 2018)<sup>[31]</sup>. Tannins hinder bacterial growth by inactivating critical enzymes or genetic material and generating hydrophobic protein complexes. The bacterial cell will progressively die as a result of this contact. (Saputra O *et al.*, 2016)<sup>[32]</sup>.

#### Flavonoids

Flavonoids are a class of natural chemicals that contain phenolic structures that vary and phenolic compounds with low molecular weight. They are broken down into numerous categories: chalcones, flavones, flavanols, and isoflavones (Panche *et al.*, 2016)<sup>[25]</sup>. Flavonoids are powerful antioxidants that act as free radical scavengers, metal chelators, and fat oxidation inhibitors. Because flavonoids have hydroxyl groups on the third carbon, a double bond between the second and third carbon, a carbonyl group in the fourth carbon position, and are polyhydroxylated in aromatic rings A and B, they have this structure. (Hasim YA *et al.*, 2019)<sup>[10]</sup>. Magnesium (Mg) and concentrated hydrochloric acid (HCl) reagents were used to identify flavonoid components in an extract of *Averrhoa bilimbi* leaf (Yanti S *et al.*, 2019)<sup>[11]</sup>. The goal of adding Mg powder is to create bonds with carbonyl groups in flavonoid compounds. The addition of HCl results in the formation of flavylium salt, which is distinguished by its orange- red colour. The flavonoids were decreased by Mg metal, resulting in the creation of flavylium salts, according to the findings. In addition to Mg and HCl, the flavonoid test of *Averrhoa bilimbi* extract reveals red deposits, suggesting the presence of flavonoid components in the sample. (Andayani R *et al.*, 2014)<sup>[12]</sup>. Flavonoids interact with bacterial cell walls, bind to extracellular proteins, and inactivate proteins to decrease bacterial cell metabolism (Andayani R *et al.*, 2014)<sup>[12]</sup>. The difference in polarity between the lipid contents of bacterial cells and the alcohol groups in flavonoid compounds can be used to separate flavonoids (Rusdianan 2018)<sup>[31]</sup>. Through hydrogen bonding, both will form compounds with bacterial lipids. The cell wall and cytoplasmic membrane will

become unstable as a result of this scenario, and the bacterial cell will lose its biological function. Additionally, bacterial cell permeability will be affected, causing bacterial cells to lyse or break, resulting in bacterial cell death (Saputra O *et al.*, 2016) [32]. Flavonoids are one of the chemicals that can help to lower total cholesterol and prevent hypercholesterolemia. Hypercholesterolemia is a disorder in which total cholesterol levels in the blood rise above normal, increasing the risk of heart and blood vessel damage. (Saraswati R *et al.*, 2018) [7]

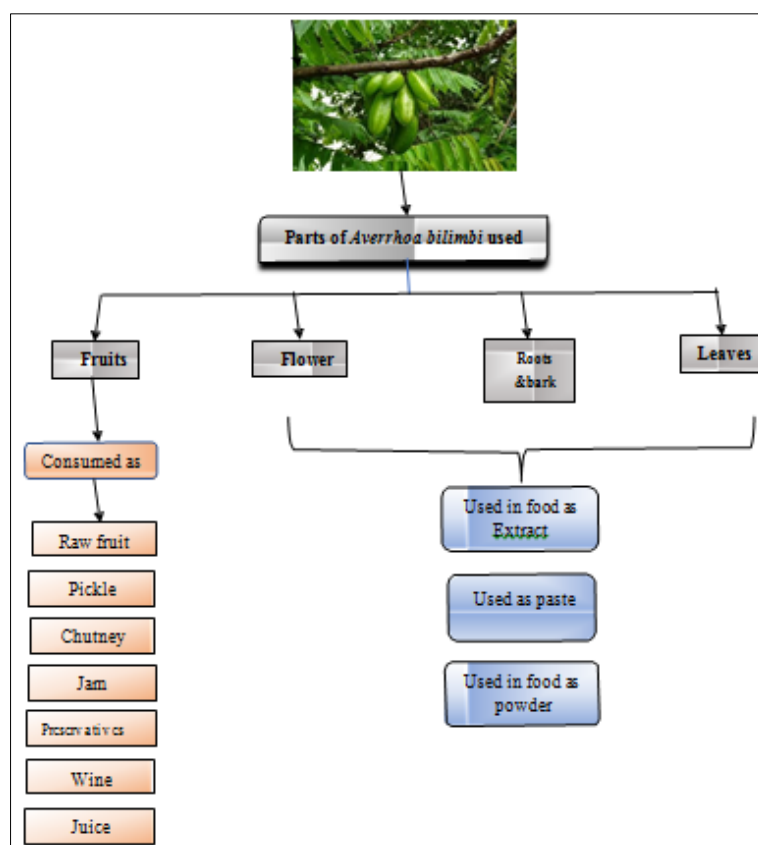
### Phenols

Phenolic compounds are a type of secondary metabolite with a low toxicity level. Phenolic compounds include molecules with one phenol ring, such as phenolic acids and phenolic alcohols, as well as polyphenol structures, such as aromatic rings with hydroxyl groups. A more active residue such as methyl, hydroxyl, or acetyl can be substituted for the phenolic molecule, which is normally generated by at least one phenyl ring (Dzialo M *et al.*, 2016) [26]. The Follin Ciocalteu technique was used to evaluate the phenolic content of *Averrhoa bilimbi* leaf extract (Hasim YA *et al.*, 2019) [10]. The Follin Ciocalteu technique is based on the creation of blue complexes that may be detected using a spectrophotometer at a wavelength of 765 nm. The extract of *Averrhoa bilimbi* leaf contained  $39.03 \pm 0.25$  g GAE / mg total phenolic with gallic acid derivatives in ethanol, according to the findings. Antibacterial, anti-inflammatory, antithrombotic, antiviral, hepatoprotective, anticancer, antiallergic, and antioxidant characteristics are all found in phenolic compounds. When the cytoplasmic membrane of the pathogen cell is damaged, H<sup>+</sup> ions from phenol components and flavonoids attack the phosphate group, breaking down the phospholipid molecules

into glycerol, carboxylic acids, and phosphoric acids. The cytoplasmic pathogen cell membrane is therefore destroyed. Food materials or nutrients required for pathogen cell metabolism will be prevented by cytoplasm damage. (Saputra O *et al.*, 2016) [32]. Phenolic chemicals in plants may give distinct colours, tastes, and scents to certain plant sections. (Hasim YA *et al.*, 2019) [10].

### Triterpenoids

Terpenoids are hydrocarbons that have been oxygenated, hydrogenated, or dehydrogenated. Triterpenes are hydrocarbon-based terpenoids that do not include any heteroatoms. Triterpenoids are triterpenes that have been functionalized. The characteristics of these chemical compounds are not steam volatile. (Battineni JK *et al.*, 2018) [27]. The presence of triterpenoid content in *Averrhoa bilimbi* extract is demonstrated by the production of red colour in the solution after adding CHCl<sub>3</sub>, anhydrous acetic acid, and H<sub>2</sub>SO<sub>4</sub> in the triterpenoid test. (Andayani R *et al.*, 2018) [12]. Triterpenoids are antibacterial chemicals that block DNA and macromolecular synthesis, preventing bacterial cell division. *Ligustrum* triterpenoid substances may limit the cyclooxygenase enzyme's ability to convert arachidonic acid into prostaglandins, an inflammatory mediator. (Hasim YA *et al.*, 2019) [10]. Inhibition of macromolecular synthesis in bacteria can also destroy the bacterial cell membrane (Andayani R *et al.*, 2018) [12]. The antimicrobial activity mechanism of triterpenoids can be done by damaging the cytoplasmic membrane lipid fraction. This will cause the membrane or cell wall to be lysis, not formed, or formed imperfectly. The mechanism of tannins, flavonoids, phenols, and triterpenoids can damage the cytoplasmic membrane with different mechanisms (Saputra O *et al.*, 2016) [32].



**Fig 1:** Industrial uses of *Averrhoa bilimbi*

**Table 1:** Nutritional Composition of *Averrhoa bilimbi*

Proximity (Cj Castro, 2021) [2]	Amount	% DV
Moisture	94.2-94.7g	N/D
Carbohydrate	6.3 mg	N/D
Energy(kcal)	27	N/D
Protein	0.61g	1.22%
Total dietary Fiber	0.6g	1.58%
Ash	0.31-0.40g	N/D
Minerals (Bhaurav T. <i>et al.</i> , 2014)	Amount	%DV
Calcium	3.4mg	0.34%
Iron	1.01mg	12.63%
Phosphorus	11.1mg	1.59%
Vitamins (Zakaria ZA <i>et al.</i> , 2013)	Amount	%DV
<b>Water-soluble vitamins</b>		
Vitamin B1	0.01mg	0.83%
Vitamin B2	0.026mg	2.00%
Vitamin B3	0.302mg	1.89%
Vitamin C	15.5mg	17.22%
<b>Fat-soluble vitamins</b>		
Beta Carotene	0.035 µg	N/D

### Disease management: Antibacterial

Studies show that *Averrhoa bilimbi* can be utilised as an antibacterial agent due to the phytochemical components contained in the plant (Kumar KA *et al.*, 2013) [17]. *Averrhoa bilimbi* extract is used to treat recurrent aphthous stomatitis (Nakhil U *et al.*, 2019) [3]. In a nutshell, the procedure is as follows: The *Averrhoa bilimbi* was macerated in 70% ethanol and evaporated after extraction. *Staphylococcus aureus*, a bacteria that affects the oral mucosa in a condition of necrosis, inflammation, and abscess, was tested on the *Averrhoa bilimbi* extract gel. The quantity of inhibition zone created was used to determine the antibacterial activity of *Averrhoa bilimbi* extract gel. The average width of the bacterial growth inhibition zone increased with increasing concentrations of *Averrhoa bilimbi* extracts utilized, according to the findings. The presence of flavonoid, tannin, and saponin, which has bactericidal qualities, promotes this. (Nakhil U *et al.*, 2019) [3]. *Aeromonas salmonicida* Smithia bacteria are inhibited by *Averrhoa bilimbi* fruit juice in Sangkuriang catfish (Purnamasari *et al.*, 2015) [15]. In summary, the experiment began with the injection of *Aeromonas hydrophila* into Sangkuriang catfish in order to obtain the identical ill fish. The wound diameter, percentage of fish healed, blood count (calculation of total leukocytes and total erythrocytes), survival and absolute length growth, as well as absolute weight growth, were all measured. Sangkuriang catfish that rely solely on their immunity take longer to recover than those immersed in *Averrhoa bilimbi* fruit solution. The treatment with a 0.2 percent concentration of *Averrhoa bilimbi* solution yielded the highest percentage of recovered Sangkuriang catfish. After being immersed in *Averrhoa bilimbi* solution, the quantity of red blood cells (erythrocytes) in Sangkuriang catfish increased and was inversely related to the amount of white blood cells (leukocytes). The fruit of *Averrhoa bilimbi*, which has been examined, includes vitamin C and flavonoids, which can boost the immune system, aid in collagen synthesis, and function as an antibiotic. (Purnamasari *et al.*, 2015) [15].

### Antidiabetic

On diabetogenic drugs induced mice, the anti-diabetic efficacy of *Averrhoa bilimbi* leaf extracts was investigated. In

summary, the researchers utilised alloxan monohydrates, which can cause hyperglycemia in mice. This drug was dissolved in 0.9 percent sodium chloride and then given intraperitoneally in a single dose of 250 mg/kg bb into mice. The results showed that blood glucose levels may be brought back to normal using an ethanol solvent and a dose of 125 mg/kg of *Averrhoa bilimbi* leaf extract. By limiting glucose absorption in the stomach and increasing insulin secretion by pancreatic beta cells via calcium metabolism regulation, flavonoid components in extracts can lower blood glucose levels in experimental mice. Flavonoids are antioxidants, meaning they can protect alloxan monohydrate against free radicals. (Sovia E *et al.*, 2015) [29].

### Liver recovery

*Averrhoa bilimbi*, which contains several types of polyphenols, has a lot of promise as a raw material for liver repair. *Averrhoa bilimbi*, for example, was utilised in a study to treat liver damage in rats (Nagmoti DM *et al.*, 2010) [30]. Acetaminophen (paracetamol), environmental pollutants, harmful drug habits, alcohol, and other circumstances cause the majority of liver damage. (Selvam N *et al.*, 2015). Antipyretic drug paracetamol causes excessive liver necrosis in humans, allowing the liver to generate enzymes and finally cause hepatotoxicity. The experimental results suggest that *Averrhoa bilimbi* possesses hepatoprotective effect, as evidenced by the improved and anticipated structure of liver tissue, glomeruli, and cardiac tissue. (Selvam N *et al.*, 2015) [28].

### Value added products from bilimbi

One option to address the expense and challenge of acquiring adequate nutrition at a cheaper price is to process fruits into a staple commodity, especially if it optimises the use of easily accessible and underused fruit as a source of food and nutrients (Castro J. *et al.*, 2021) [2]. Bilimbi is one of underused fruits in Malaysia. The fruit is used as a flavour and a preservative in Costa Rica. As a substitute of raw mango and tamarind, *A. bilimbi* is used to make chutneys. Flowers are also picked, cleant, air-dried, and stored in sugar syrup (Ravindran, 2016) [6]. Inflammatory diseases are treated with a fruit syrup (Yap, Jr., 2018) [8].

### Jam

The bilimbi, which has a multitude of health advantages and may even be used as a medicine to cure certain illnesses, is one of the most prevalent yet underused fruits in the Philippines. Because they are plentiful in many parts of the nation, the bilimbi in coconut water jam were developed to maximise their nutritious characteristics while also improving their flavour. Vitamin C, Vitamin B2, Vitamin B3, Vitamin B1, iron, protein, carbs, and other minerals were present by the processed bilimbi fruit blended with necessary components in a bilimbi jam. With an acceptable concentration of 50%, coconut water improved the sensory qualities of the bilimbi jam in terms of flavour and texture. The development of value-added goods from bilimbi fruits, such as bilimbi jam, can provide healthy nutrition and income to the community. (Castro J. *et al.*, 2021) [2].

### Juice

The goal of the research was to determine the profile of bilimbi fruit juice in terms of ingredients and costing, tools



and equipment, procedure, shelf life, nutritive value, microbial analysis, sensory qualities, and level of preferences in three different treatments in terms of colour, flavour, aroma, and texture. The ingredients and tools used to make the bilimbi fruit juice were found to be simple, inexpensive, and readily accessible in the local market. At room temperature, the shelf life ranged from 1 to 7 days (Jessica D. *et al.*, 2020)<sup>[4]</sup>.

### Pickle

Bilimbi (*Averrhoa bilimbi* L.) is a long-lived, underutilized perennial evergreen plant that is commonly grown in home gardens and belongs to the oxalidaceae family. Bilimbi pickle was made with bilimbi fruits, salt, cinnamon, cardamom, cloves, and black pepper, among other things. Prior to preparing the product, formulas and methods were developed. Osmotic dehydration, salt usage, natural acidic environment within container, antibacterial and antioxidant characteristics owing to added spices, and heat and sun drying procedures all helped to extend the shelf life of the product. The study found that the product had a high commercialization and marketability potential due to its long storage life and low cost. (Gunawardhana *et al.*, 2020)<sup>[13]</sup>.

### Jelly candy

Jelly candy is a chewy sweet that falls within this category. Jelly candy is a sweet created from water or juice and a gel-forming substance that appears translucent and has an elastic texture. Bilimbi's application as a food flavouring component is typically confined. There are also alternative methods for processing bilimbi to make it a qualified food product with economic worth, such as turning it into jelly candy. Bilimbi jelly candy, especially candy with a high economic value, can be utilised as an alternate snack. (Laily Hidayati *et al.*, 2017)

### Conclusion

*A. bilimbi* is an essential medicinal plant used in herbal medicine to cure a variety of illnesses and promote good health and well-being. The extensive pharmacological study has established the theoretical basis for the medicinal uses of *A. bilimbi*'s leaves and fruits in treating various diseases, including diabetes, hypertension, and microbial infections. Compared to many pharmacological studies, few preliminary phytochemical studies on this plant have been published. The compounds found so far are primarily volatile oils, fatty acids, and long-chain hydrocarbons with low medicinal value. Despite *A. bilimbi*'s advantageous use of complementary medicine and its clinically validated pharmacological practices, knowledge is scarce on the bioactive compounds contained in this plant.

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