

Averrhoa Bilimbi and its Health Benefits

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Abstract

Averrhoa bilimbi is principally cultivated for medicinal purposes in many tropical and subtropical countries of the world. It is a multipurpose, long-lived tropical plant commonly known as –Bilimbi, Cucumber Tree belonging to family Oxalidaceae. The plant has an enormous value since most of the parts like flowers, fruits, leaves, bark, seeds, roots or the whole plant are used as alternative medicine to treat a variety of diseases. Survey about this plant shows that *A. bilimbi* is mainly used as a best medicine in the treatment of hypertension, diabetes mellitus and antimicrobial agent. The main objective of this review is to accumulate and organize literatures based on health benefits of *A. bilimbi*. It holds great value in the complementary and alternative medicine. Hence, this paper presents an overview on covering the biology, and various commercial, therapeutic applications, and comprehensive review on the ethno-medicinal uses, different chemical constituents and pharmacological activities

Keywords: *Averrhoa bilimbi*; Antibacterial activity; Proximate composition; Traditional uses

Introduction

Plants are the main source of drugs that being used from the ancient times as herbal remedies for the health care, prevention and cure of various diseases and ailments. *Averrhoa bilimbi* L. of family oxalidaceae, widely cultivated throughout tropical countries [1], for their fruits as these fruits are nutritionally rich. It is commonly called as Bilimbi and medicinally used as a folk remedy for many symptoms. There are many uses in traditional medicine such as fruit conserves or syrups are used for coughs, fevers, and inflammation. Young fruits are waxy shining and green, while mature are yellowish in colour. Fruits are ellipsoid, obovoid or nearly cylindrical, lobed in structure having 4-5 ridges. The size ranges from 5.5 - 7cm long and up to 2-3cm in diameter. On an average 7 seeds are present in a fruit. Flowering in Bilimbi starts around mid-February to late March and fruiting lasts up to late December to early January. Fruit taste is sour. It is widely cultivated in the tropics and its origins are not yet clear.

Nevertheless, Correa (1926) reported that it is native of India, from where it was brought to Brazil centuries ago. In Brazil, this tree is cultivated in the states of Rio de Janeiro, Amazonas, Pará and Santa Catarina, but the distribution of its fruits is limited. In these places, it is locally known as "bilimbi", "bilimbi no", "biri-biri", "caramboleira amarelle" or "limão de caiena". Bilimbi is a small tree up to 15 meters high. Fruits are fairly cylindrical with five broad rounded longitudinal lobes, and produced in clusters (Figure 1-3). During maturity stage occurs the maximum increase in fruits weight and dimensions, and their external green colour changes into light yellow [2]. Bilimbi fruits are very sour, and used in the production of vinegar, wine, pickles and in the preparation of Hindu dishes. Due to high content of oxalic acid, rich in vitamin C, with high level of antioxidants. The vitamin C levels in ripe and half-ripe bilimbi harvested in the same season were statistically different. Ripe fruits harvested during dry season had the highest vitamin C level. This result may have been influenced by climatic factors [1]. As expected, during the dry season, an increase of photosynthetic activity (induced by rising solar radiation and reduced average seasonal rainfall) produces higher levels of vitamin C, since this vitamin is synthesised from hexose sugar precursors. In spite of the low levels of vitamin C in bilimbi, the ripe fruit has significant amount of this vitamin.

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Figure 1: Bilimbi flowers.



Figure 2: Bilimbi fruit clusters.



Figure 3: Harvested bilimbi fruits.

Therefore, the medicinal use of this fruit against scurvy, which was recommended by Correa *Averrhoa bilimbi* is a potent plant for future research since it has antidiabetic, antihyperlipidemic and antibacterial properties. The fruit has juicy and firm flesh with greenish colour and when its ripe fruit are become soft. Bilimbi fruits are sour in taste and its acidity is very high [3]. Bilimbi is a natural source of Antioxidant, Vitamin B and C and Iron, Phosphorus [4]. Bilimbi fruit has a shorter shelf life due to its juiciness. After they harvest it has shelf life about 4-5 days and rapidly gone waste [5]. Post-harvest losses of bilimbi fruit can be seen. Nevertheless, it can be preserved under certain traditional methods like drying, pickling, jams, jellies...etc.

These are also traditional used, preserved methods of bilimbi in Sri Lanka. The mixture of preservation is used to extend the shelf life of the product. The products can be stored around six months to 1 year in a glass bottle without refrigerating. The product can

be added as the sourness enhancer of condiment, like salted lime pickles. As above mentioned, bilimbi is a seasonal crop, therefore consumers can consume bilimbi flavour in off season as well by adding bilimbi pickles, jams, jellies as desired [6].

Origin and Distribution

Perhaps a native of the Moluccas, the bilimbi is cultivated throughout Indonesia; is cultivated and semi-wild everywhere in the Philippines; is much grown in Ceylon and Burma. It is very common in Thailand, Malaya and Singapore; frequent in gardens across the plains of India, and has run wild in all the warmest areas of that country. It is much planted in Zanzibar. Introduced into Queensland about 1896, it was readily adopted and commercially distributed to growers.

Vernacular Names

The bilimbi (*Averrhoa bilimbi*) is a member of the Oxalidaceae family. It is closely allied to the carambola but quite different in appearance, manner of fruiting flavor and uses. The bilimbi is known locally as “khamrak” or “kornishore” and in other countries known as by the English (cucumber tree, bilimbi, tree sorrel); Filipino (kamias); Spanish (Tiriguro, Pepino De Indias, Mimbros, Grosella China, Vinagrillo); Thai (Naling pring, Taling pling).

Taxonomy

Characteristics of Bilimbi Fruits

Ripe bilimbi fruits have thin skin, yellowish-green color, soft texture and a peculiar smell, which resembles the one of carambola, a fruit of the same botanical family. Half-ripe fruits have firm texture and imperceptible smell.

Effect of drying on physical properties

Higher drying temperatures gives less drying time, a lighter colour but greater product shrinkage, whilst pre-treatment can reduce product shrinkage and drying time and can also give good texture properties (Table 1-5). pre-treatment and the drying temperature are important to improve mass and heat transfer as well as the product characteristics such as colour, shrinkage and texture [7]. Ripe fruits had the highest levels of TSS and vitamin C and lowest levels of oxalic acid, independently of weather conditions. The results showed that maturity stage influenced on physicochemical characteristics of bilimbi fruits [8].

Table 1

S.NO	State	Name
1	Marathi	Bilimbi
2	Tamil	Pulima
3	Malayalam	Vilumpi
4	Telugu	Gommareku
5	Kaneda	Bilimbi
6	Konkani	Bimbul
7	Manipuri	Heinoujom
8	Hindi	Bilimbi

Table 2: Taxonomy.

Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermetophyta
Division	Magnoliophyta
Class	Dicotyledone
Subclass	Rosidae
Order	Oxalidales
Family	Oxalidaceae
Genus	Averrhoa
Species	Bilimbi L.
Synonyms	Cucumbertree sorreltree

Table 3: Physical Features.

S.NO	Characters	Content
1	Colour	Greenish yellow
2	Texture	Firm 10.41±0.87
3	Fresh weight(g/fruit)	0.55±0.17
4	Dry weight(g/fruit)	4.95±0.54
5	Length(cm)	1.94±0.18

Table 5: Chemical characteristics in ripe and half ripe bilimbi fruits harvested on dry and rainy season.

S.NO	Component	Dry Season		Rainy	Season	Reference
		Ripe Fruits	Half Ripe Fruits	Ripe Fruits	Half Ripe Fruits	
1	Oxalic acid (gm/100g)	8.57	9.33	9.82	10.32	Lueci dos Santos Lima et al. (2001)
2	Vitamin C (mg/100g)	60.95	32.23	36.68	20.82	
3	TSS (° Brix)	5.06	4.34	4.64	3.94	

Phytochemical constituents

The extract of various parts of *Averrhoa bilimbi* is medicinally used as a folk remedy for many symptoms and showed significant pharmacological activities so it is necessary to perform further investigation to isolate such pharmacological active compounds which can be used in production of novel drugs for various diseases [9].

Toxic effect

This fruit contents high level of oxalate. Acute renal failure due to tubular necrosis caused by oxalate crystal has been noted. bilimbi fruit juice should be avoided in CKD and on dialysis patients [10]. *Averrhoa bilimbi* species, and exhibits similar biochemical characteristics to star fruit [11]. Freshly made concentrated juice has a very high oxalic acid content and consumption carries a high risk of developing Acute Renal Failure (ARF) by deposition of Calcium Oxalate crystals in Renal Tubules. Acute Oxalate Nephropathy (AON) due to secondary oxalosis after consumption of Irumban Puli Juice is uncommon [12]. Oxalic acid has been identified as the principal acid in the carambola (*Averrhoa carambola* L.) and the bilimbi (*A. bilimbi* L.) (2). While quantitative levels have been reported for carambola, oxalic acid has only been reported qualitatively for bilimbi. The habitual use of fruits with

6	Width(cm)	2.04±0.17
7	Thickness(cm)	9.54±0.48
8	Volume(ml)	6.7±0.88
9	No. of seeds per fruit	5.45±0.76
10	No. of ridges per fruit	

Table 4: Proximate composition of *Averrhoa Bilimbi*.

S.NO	Component (gm/100gms)	Proximate Composition (%)	Reference
1	Moisture	16.84±0.36	
	Ash	4.62±0.01	Wan et al. [28]
	Carbohydrate	32.02±3.15	
	Protein	11.50±0.36	
	Fat	3.38±2.43	
	Total dietary fibre	15.31±2.40	
2	Moisture	16.9	Yan et al. [28]
	Ash	4.65	
	Carbohydrate	34.1	
	Protein	11.5	
	Fat	3.48	
	Total dietary fibre	15.5	

high oxalic acid levels could lead to the ingestion of levels that may result in significant nutrient-toxicant interactions in the Guyanese population [13]. Bilimbi fruit extract shows the protective effect to the histological structure damage of mices renal cells induced by reheated palm oil. The increasing of dose of the Bilimbi fruit extract improves the protective effect to mices renal cells [14]. The combination of doxorubicin with BM-extract significantly increased the mean survival time (MST) in EAC-mice. BM-extract treatment modulated the antioxidants both in heart and liver tissues of EAC-mice. For mechanistic approach, BM-extract showed in vitro antioxidant activity (measured by DPPH and FRAP assay) and inhibited intracellular generation of ROS and nitrite in RAW264.7 cells.

Conclusion: The protection from doxorubicin-induced cardiotoxicity by BM-extract was attributed to its antioxidant activity and inhibition of intracellular free radical generation [15].

Vitamins and mineral analysis

Averrhoa bilimbi L. (Oxalidaceae) is widely distributed and cultivated throughout tropical countries for its fruits. Parts such as Leaves, Bark, Fruits are widely used in medicine as a folk remedy for many symptoms. fruit is good source of minerals such as Potassium, Phosphorus, Nitrogen, Calcium, Magnesium and Iron

suggesting its use as a potential [16]. Vitamins are crucial to all life functions. Vitamins are also called as co-enzymes because they work with enzyme and enable them to trigger all body processes. Among the vitamins, the Vitamin C is an important vital amine to maintain the body in good health. The main sources of Vitamin C are from fresh fruits and vegetables. The fruit juice contains Vitamin C and in addition to that it contains glucose and protein. The nutritive contents were estimated. The Antibacterial activity of above two plants fruit juice were carried out in order to ascertain the disease resistance property [17]. Raw bilimbi fruit at the harvesting stage (yellowish green) was autoclaved for 3 hours at 121 °C, 15psi and analysed for ash, vitamin C, titratable acidity, pH and colour. Autoclaved bilimbi fruit contains 0.65% ash which was significantly ($p < 0.05$) higher than the raw bilimbi (0.50%). pH slightly increased (2.78) after autoclaving. Vitamin C content (12mg/100g) and titratable acidity which was reported as oxalic acid (0.34mg/100g) were lower in the autoclaved fruits and the fruits were darker based on the 'L' value (42.63). Thus, autoclaving affects some of the physicochemical properties of the bilimbi fruits [18].

Anti-bacterial effect

The antimicrobial activity was highest for the fruit extract against the Gram-negative *Salmonella paratyphi* (23.0 ± 0.50mm) and the Grampositive *Bacillus megaterium* (19.0 ± 0.40mm) bacteria, somewhat weaker against the *Staphylococcus aureus*, *Bacillus subtilis*, while with the leaf extract poor activity was observed against all 12 bacteria [19]. Ethanol extract showed scavenging property against DPPH (82.82mg GAE/ g DW) and gave a more inhibitory effect on the growth of *Salmonella sp.*, *Escherichia coli*, and *Staphylococcus aureus*. The phenolic compounds might be associated with the antioxidant and antibacterial activities of this extract [20].

Anti diabetic effect

The phyto constituents like flavonoids, saponins and triterpenoids have been isolated from *Averrhoa bilimbi* increased glucose uptake and glycogen storage in-vitro rat hemi diaphragm technique proved that *Averrhoa bilimbi* is having the wide anti diabetic activity [21]. *Averrhoa bilimbi* Linn. (Oxalidaceae) is a medicinal plant and is reported to possess hypoglycemic activity [22]. Hyperglycemia-mediated oxidative stress plays a major role in the development of diabetic complications. *Averrhoa bilimbi* Linn. (Oxalidaceae) is a medicinal plant with fruits reported to possess antidiabetic activity. bilimbi fruits at a dose of 25mg/kg body weight for 60 days. Serum Glucose, Glycated Hemoglobin, Plasma Insulin, Hepatic Toxicity markers, Antioxidant Enzymes, Lipid Peroxidation products, and liver histopathology were assayed checked after 60 days of extract treatment. Diabetic rats administered ABAEE showed a significant decline in Serum Glucose, Glycated Hemoglobin, and also significantly increases the level of plasma insulin, as well as a notable attenuation in thiobarbituric acid-reactive substances, conjugated dienes, and hydroperoxides. ABAEE also modulated hepatic antioxidant potential by significantly increasing the activities of catalase, glutathione peroxidase, glutathione reductase, superoxide dismutase, and reducing glutathione content [23].

Antimicrobial properties

The extracts have stronger antimicrobial effects against Gram negative bacteria, *Salmonella spp.* with inhibition zone of 12mm at young fruit, 11mm at mature fruit and 9.3mm at ripe fruit than *Escherichia coli* and *Pseudomonas aeruginosa*. The antimicrobial properties are influenced by the maturity stages of the fruit especially at early stage of maturity [24]. *A. bilimbi* fruit has been used as traditional remedies to cure fever, coughs, inflammation, diabetes and hypertension Concentration of 1000µg/ml of the extracts were diffused into blank filter paper disc and placed onto cultured agar. The preliminary screening for both extracts showed inhibition activity against all tested bacteria. The Minimum Inhibitory Concentration (MIC) was performed by using microdilution broth method. The MIC value of aqueous extract are the same for all organism tested which is 62.5µg/ml. The MIC value of ethanol extract is 62.5µg/ml for *S. aureus*, *E. coli* and *S. typhimurium* while *B. cereus* showed slightly lower MIC value which is 31.25µg/ml. The Minimum Inhibitory Concentration (MBC) was done to confirm the MIC value. All tested organism showed the same MBC value when treated with aqueous extract which is 125µg/ml. The MBC value of ethanol extract is 125µg/ml for *S. aureus*, *E. coli* and *S. typhimurium* while *B. cereus* showed lower MIC value which is 62.5µg/ml [25].

Anticoagulant activity

The high level of oxalic acid in *A. bilimbi*, which range from 10.5 to 14.7mg/g in green, unripened fruit and 8.45 to 10.8mg/g in ripe fruit could provide the anticoagulation effect [26].

Anti Inflammatory effect

The treatment with *Averrhoa bilimbi* L. fruit extract has shown a significant antioxidant activity in the UC condition by reducing the levels of NO and enhancing the levels of SOD and GSH in the colon tissue [27].

Antioxidant capacity

Total phenolic content was higher in carambola although bilimbi yielded more total flavonoid. Vitamins A, C, and E contents of bilimbi were also higher than carambola [28]. *A. bilimbi* fruit extract showed strong cytotoxic potential with an LC50 value of 5.011µg/ml in brine shrimp lethality bioassay. Our results suggest that, in addition to having cytotoxic potential, *A. bilimbi* fruits are rich in polyphenolic antioxidants with strong radical scavenging capacity [29]. The extract of Bilimbi fruit decrease SGPT level in mice induced by reheated palm oil [30].

Anticancer activity

The methanolic fruit extract exhibited significant cytotoxic potential against MCF-7 human breast cancer cell lines with an IC50 value of 154.9µg/ml whereas an IC50 value of 668µg/ml observed for ethanolic leaf extract. The methanolic fruit extract could be considered as a source of novel anticancer compounds [31].

Anti-allergic activity

The anti-allergy effect of *Averrhoa bilimbi* Linn. fruit water extract (AFWE) was examined using RBL- 2H3 cells. At first, the

cytotoxicity effect of AFWE was determined by WST-8 assay. The release of β -hexosaminidase by RBL-2H3 cells was also measured to evaluate degranulation suppression activity of AFWE. Lastly, calcium assay was employed to investigate the intracellular calcium concentration ($[Ca^{2+}]_i$). [32].

Ethnomedicinal Uses

A. bilimbi is mainly used as a folk medicine in the treatment of diabetes mellitus, hypertension, and as an antimicrobial agent. Several pharmacological studies have demonstrated the ability of this plant to act as Antidiabetic, Antihypertensive, Thrombolytic, Antimicrobial, Antioxidant, Hepatoprotective, and Hypolipidemic agent. *A. bilimbi* holds great value in the complementary and alternative medicine as evidenced by the substantial amount of research on it [33].

Value Added Products

Ingredients and tools in making the Bilimbi Fruit (*Averrhoabilimbi*) Juice were minimal, less expensive, and were available in the locale market. Shelf life ranged for 1 to 7 days at room temperature. All treatments of "Bilimbi Fruit" *Averrhoabilimbi* Juice was liked by the respondents in all four attributes. Generally [34]. Bilimbi fruit, locally known in the Philippines as kamias in Tagalog/Filipino (National Language of the Philippines) and Iba in Waray-waray (Local dialect of Guiuan, Eastern Samar) is good to be used as flavoring for candy [35]. Bilimbi (*Averrhoa bilimbi* L.) is long lived underutilized perennial evergreen plant particularly cultivated in home gardens, belong to the family of oxalidaceae. Bilimbi pickle was prepared using bilimbi fruits and other ingredients of salt, cinnamon, cardamom, cloves, and black pepper. Formulations and procedures were created prior to prepare the product. Well matured fruits were selected and prepared product was filled into glass bottles and stored at room temperature for a week and evaluated color, aroma, and taste at an interval of one day. The product preserves by osmotic dehydration, in use of salt, by natural acidic environment within bottle, by antimicrobial and antioxidant properties due to added spices and heat and sun drying treatments as well [36].

The bilimbi can be introduced as the food flavoring as it contains high in acid and can act as souring agent. Approximately 3g of pectin should meet the sensory acceptability requirements in terms of the texture of the jam. Bilimbi fruit can be used to make a fruit jam with good sensory acceptability which suggests high market potential due to TPC that can contribute to antioxidant activity [37].

Scavenging Activity

Averrhoa bilimbi L. belongs to family Oxalidaceae. Traditionally, people use this plant (root, bark, leaves and fruits) for treating several illnesses include itches, boils, syphilis, whooping cough, hypertension, fever and inflammation. fruit extract is a rich source of phytochemicals (natural products) with biological activity. The GC-MS report on this fruit proves that natural products have pharmacologically and biologically active compounds [38]. The phytochemical screening revealed the potent source of different

phytochemical constituents on different extractives including, phenol, flavonoid, tannin that are responsible for antioxidant action. In the determination of total phenolic content, different extractives showed a significant content of phenolic compounds ranging from 50.23-68.67mg of GAE/g of extractive. The plant sample displayed significant DPPH free radical scavenging activity with highest IC50 value in crude methanolic extract (30.365?g/ml) followed by chloroform, carbon tetrachloride, pet-ether and aqueous soluble fractions having value of 32.852 ?g/ml, 36.708 ?g/ml, 50.35 ?g/ml, and 79.918?g/ml, respectively as opposed to that of the scavenging effects of BHT of 19.656 ?g/ml [39].

Hptlc Fingerprint

The fruits of *Averrhoa bilimbi* L. are used to treat skin disorders, fever, for scurvy and beneficial in diarrhoea, hepatitis and in inflammatory condition. It is also used to treat hyperlipidaemia and possess potential antibacterial and antioxidant activity. Pharmacognostical evaluation included examination of morphological and microscopical characters, physicochemical properties, phytochemical analysis, fluorescence study and HPTLC fingerprint. The powder microscopy showed the presence of simple and glandular trichomes and spiral thickening of vessels. Phytochemical screening reported the presence of carbohydrates, proteins, amino acids, flavonoids, tannins and hydrolysable tannins. The HPTLC fingerprint developed for the separation of phytoconstituents is unique to *A. bilimbi* L. fruit powder. HPTLC fingerprint has been developed; as the chemical fingerprint obtained by chromatographic techniques are strongly recommended for the purpose of quality control of herbal medicines. This unique band pattern obtained from HPTLC fingerprint can be used for the identification of *A. bilimbi* L. fruits [40].

Umami Compounds

Salted fermented fruit known as asam sunti (*Averrhoa bilimbi* L.) in Indonesia has been used as a source of umami taste. Organic acid as well as amino acid seemed to play an important role in the intense umami taste of asam sunti [41].

Conclusion

A. bilimbi is an important medicinal plant used in traditional medicine for the treatment of various ailments and in maintaining good health and well-being. *A. bilimbi*'s leaves and fruits in the treatment of several diseases including diabetes mellitus, hypertension and microbial infections. Plants are the major source for bio-active compounds they are meant for several biological activities in human and animals. As the prevalence of obesity and Diabetes mellitus are very common in our society, research on plants with antidiabetic and antibacterial properties as evidenced by the current research on the various plant parts [42-44].

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