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Phytochemical and Ethnopharmacological Review of *Aegle marmelos* Linn. (Bael)

Mahendra Kumar Sahu[1]*, Sandip Prasad Tiwari[2]

[1]MATS School of Pharmacy, MATS University, Raipur, CG 493441, India.
[2]Department of Pharmaceutical Sciences, Kalinga University, New Raipur, CG 492001, India.

Abstract

Aegle marmelos Linn. (Bael) is a fruit-bearing tree native to the Indian subcontinent. It holds a significant place in traditional medicine systems and cultural practices of the region. The aim of the study on *A. marmelos* phytochemical and pharmacological investigation of the bioactive compounds present in the plant and to elucidate their potential pharmacological activities. The goal of this research is to better understand ancient medicine and its possible uses in contemporary healthcare. A multidisciplinary approach combining botanical, phytochemical, and pharmacological approaches is required to understand *A. marmelos*. The results of a pharmacological and phytochemical study on *A. marmelos* would provide valuable insights into its potential health benefits and the bioactive compounds responsible for those effects. In summary, *A. marmelos* is a plant with significant potential for promoting health and well-being, based on both traditional wisdom and emerging scientific knowledge. Its wide range of bioactive compounds makes it an intriguing subject for further research and exploration into its therapeutic applications.

Keywords: *Aegle marmelos*, Phytoconstituents, Medicinal Property, Pharmacology

Corresponding author: Mahendra Kumar Sahu
E-mail ✉
mahendrapharma0310@gmail.com

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Introduction

Aegle marmelos Linn. (Bael) is an important medicinal tree in India, commonly known as Bael fruits, Bel, Indian Bael, Bengal Quince, Belan in English and Shivadruma in Sanskrit, Bel or Bael in Hindi [1]. Fruits are green, hard, and smooth woody shells, that belong to the family Rutaceae. Geographically occurring as wild throughout Berma and cultivated at the Sub-Himalayan tract all over India, particularly Central as well as Southern India [2, 3]. This particular variety of trees, which is around 12 meters tall, sheds its leaves every autumn. The Hindu faith holds significant mythological value for the Leaf of the AM tree, often referred to as Tripatra, which is crucial for the Lord Shiva puja. The plant has tough, 8-9 meters in height, aromatic leaves, and round-shaped fruit 5-10 cm in diameter and mucilaginous in taste. Fruits are collected in April–May [4, 5]. Each parts of this tree are used and can be utilized in various fields [6]. *A. marmelos* is a high source of different phytochemicals i.e. carotenoids, terpenoids, alkaloids, flavonoids, amino acids, tannins, organic acids fatty acids, etc [7]. The formulation of *AM* is very well-known in history and is used in dysentery and diarrhea. The root is one of the essential parts used in herbal formulations such as Dashmularisht. Leaves contain alkaloids which play a role in reducing blood sugar levels [8]. Seeds are a rich source of oil and possess antibacterial, antiprotozoal along antifungal properties. It works in dose dose-dependent manner it may cause

abortion as a result, it should not be used by pregnant women [9].

The taxonomical classification of *Aegle marmelos* is presented in **Figure 1**.

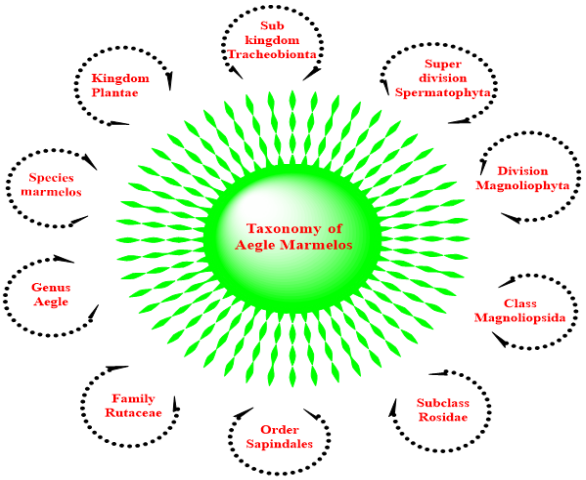


Figure 1. Taxonomical classification of *Aegle marmelos*

The aim of the study on *A. marmelos* phytochemical and pharmacological investigation of the bioactive compounds present in the plant and to elucidate their potential pharmacological activities.

Results and Discussion

Phytochemical's

A. marmelos, commonly referred to as bael or Bengal quince, Ayurveda, and Traditional Chinese Medicine both use medicinal plants as part of their long-standing regimens [10]. *A. marmelos* is well renowned for having a variety of therapeutic benefits and these are attributed to the presence of numerous phytochemicals in its different parts, including leaves, fruits, and roots. Phytochemicals are naturally occurring bioactive compounds found in plants that often contribute to their potential health benefits [11-13]. The *A. marmelos* leaves, roots, and fruits have a variety of chemical constituents Hydro-alcohol is mostly used as a solvent for the extraction of active ingredients from this plant **(Figure 2)**.

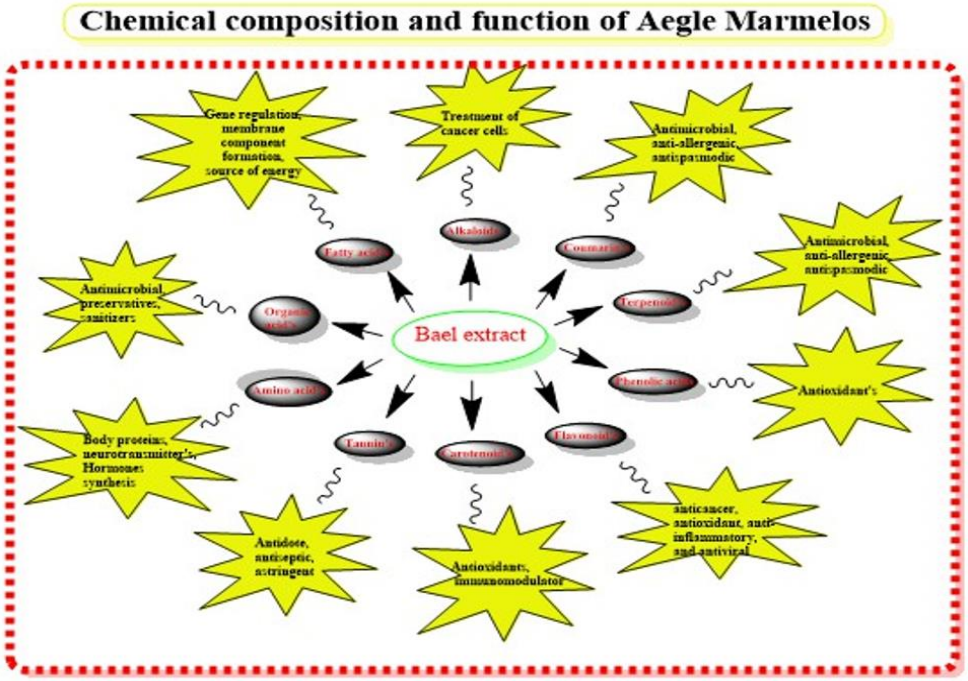
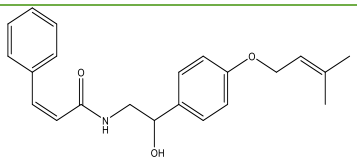
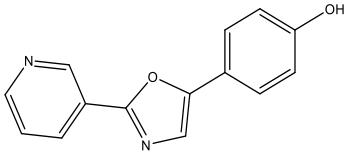
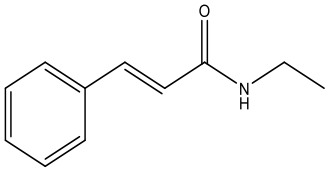
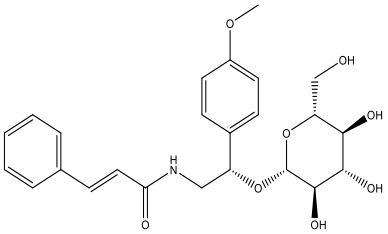
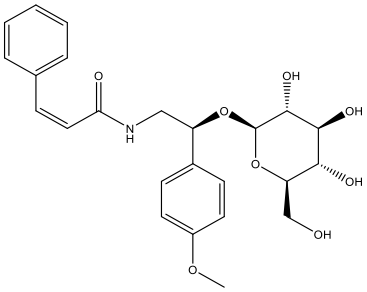
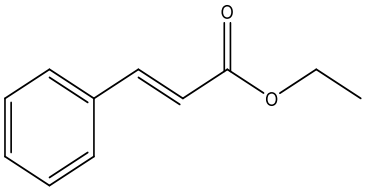
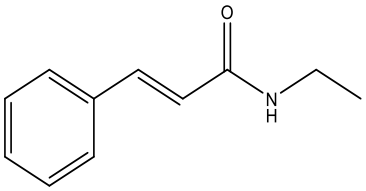
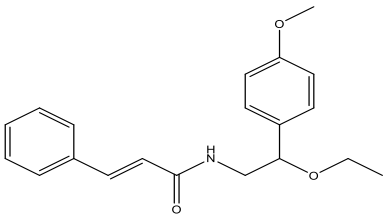
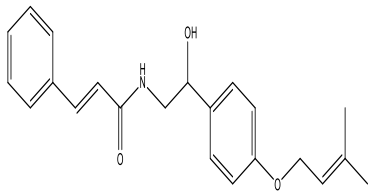
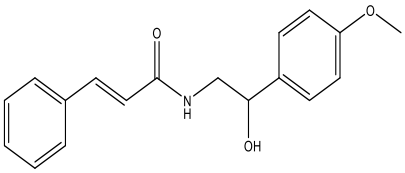
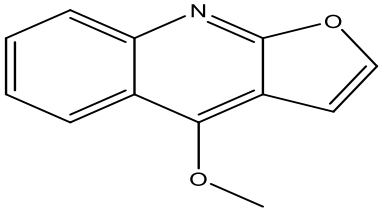
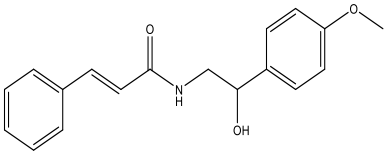
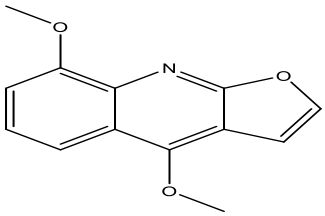
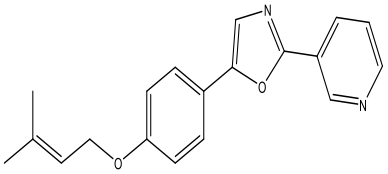
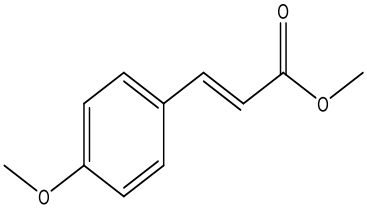
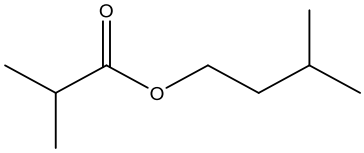
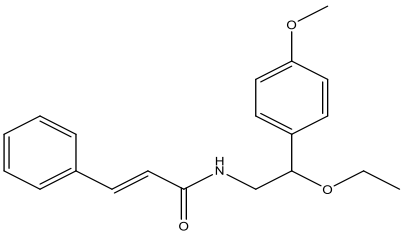


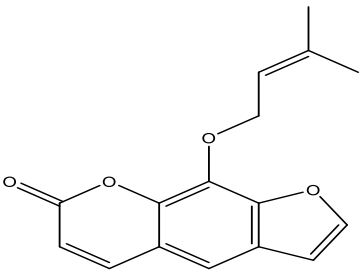
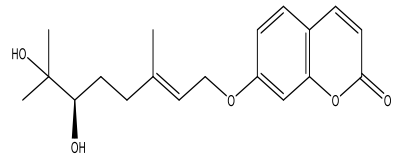
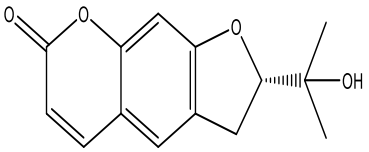
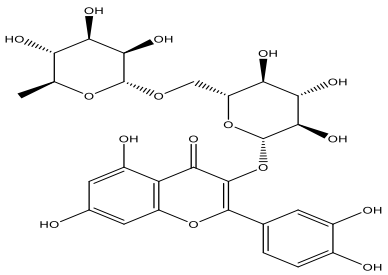
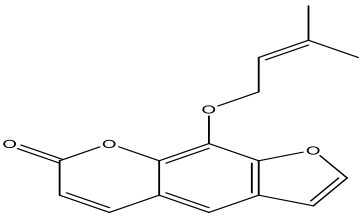
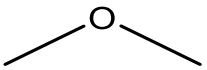
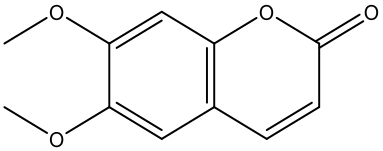
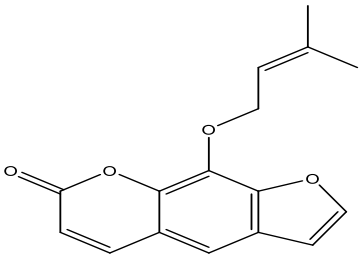
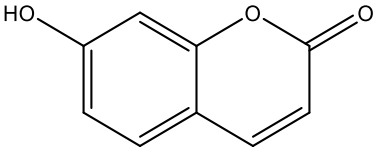
Figure 2. Phytoconstituents and uses of Bael Extract

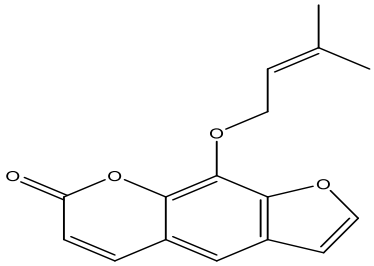
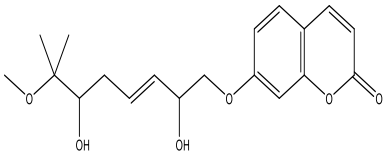
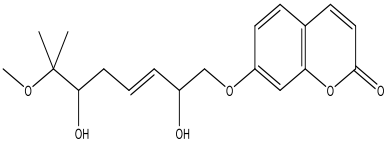
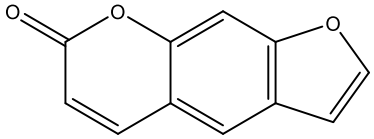
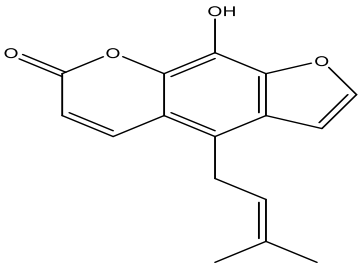
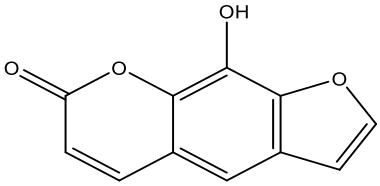
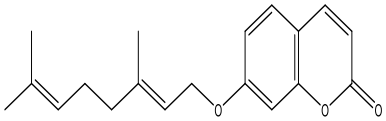
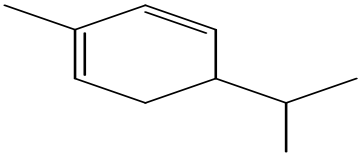
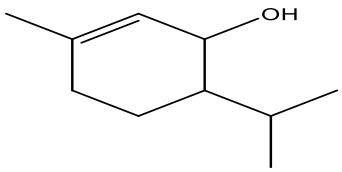
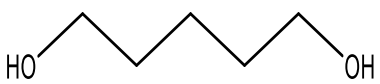
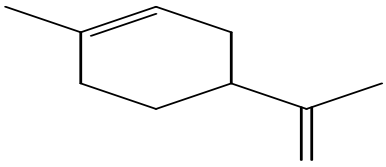
Literature surveys suggested that *A. marmelos* contains a variety of phytochemicals [14]. Alkaloids are used medicinally to treat heart conditions, reduce inflammation, and provide anesthesia. Leukaemia, renal cell carcinoma, and prostate cancer were treated with coumarin, terpenoids, and flavonoids. Phenolic as well as amino acids play's role as antioxidants and improve digestive system function **(Table 1)** [15].

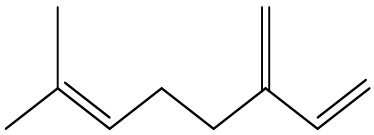
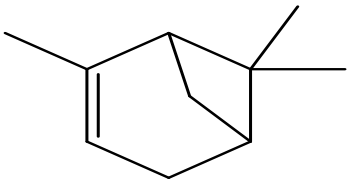
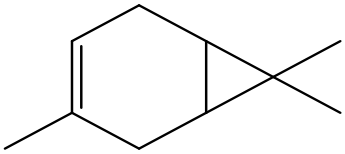
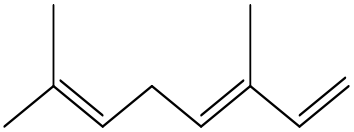
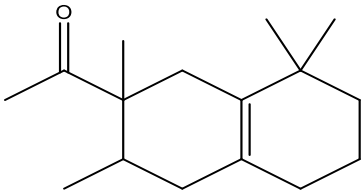
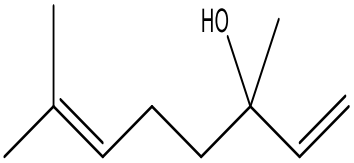
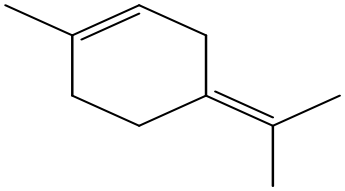
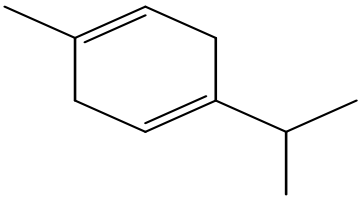
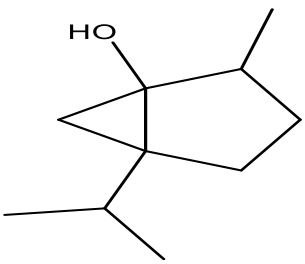
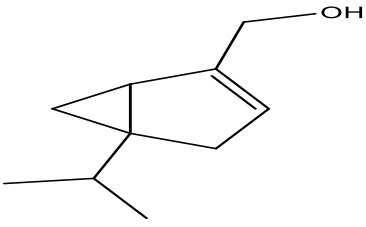
Table 1. *Eagle marmelos* chemical composition, separation technique, and medicinal uses

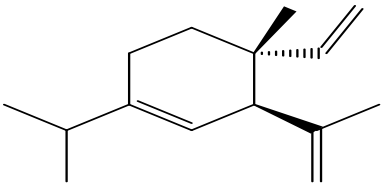
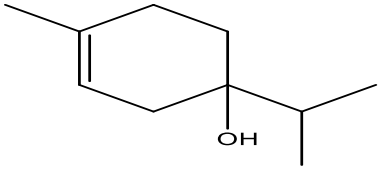
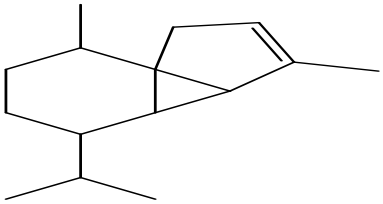
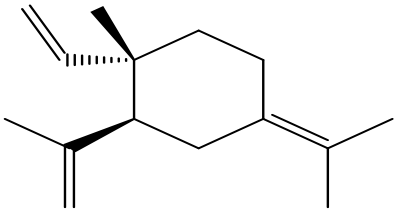
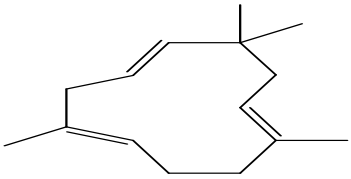
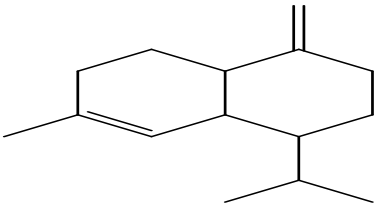
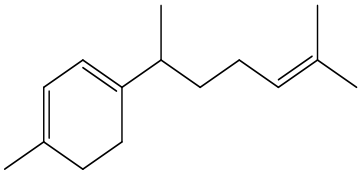
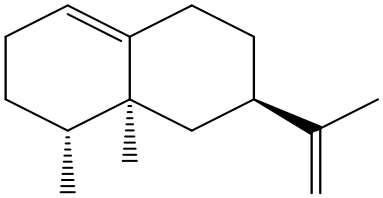
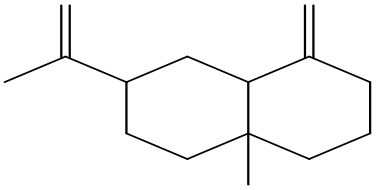
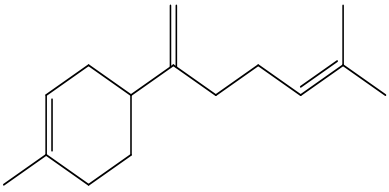
S. No.	Metabolites	Phytochemicals	IUPAC Name	Molecular structure	Extraction/ Separation Technique	Pharmacology	Reference
1.	Alkaloid's	Marmeline	(Z)-N-(2-hydroxy-2-(4-((3-methylbut-2-en-1-yl)oxy)phenyl)ethyl)-3-phenylacrylamide		Chromatography Techniques	Cardioprotective, Anaesthetic, anti-inflammatory, Anticancer	[16, 17]
		Halfordino	4-(2-(pyridine-3-yl)oxazole-5-yl)phenol				[18-20]
		Ethyl cinnamate	N-ethylcinnamamide				[21-24]
		Aegelinosides a	N-((S)-2-(4-methoxyphenyl)-2-(((2R,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)tetrahydro-2H-pyran-2-yl)oxy)ethyl)cinnamamide				[25]
		Aegelinosides b	(Z)-N-[(2S)-2-(4-methoxyphenyl)-2-[(2R,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyethyl]-3-phenylprop-2-enamide				[26, 27]
		Ethyl cinnamate	ethyl (E)-3-phenyl prop-2-enoate				[13, 28, 29]
		Ethyl-cinnamon	N-ethylcinnamamide				[30, 31]
		Ethanediamine	N-(2-ethoxy-2-(4-methoxyphenyl)ethyl)cinnamamide				[30]

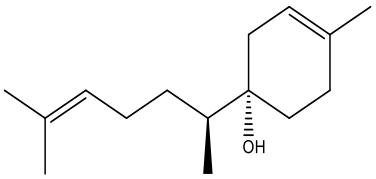
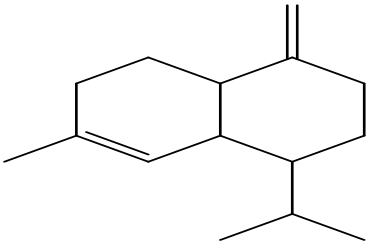
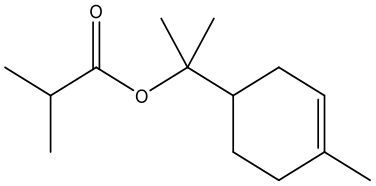
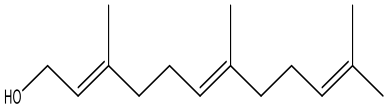
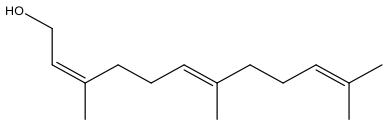
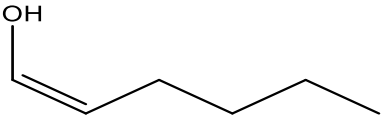
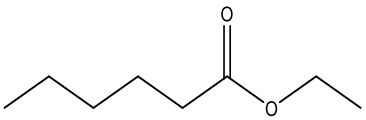
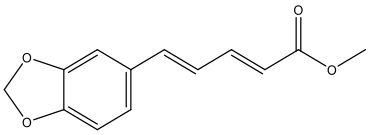
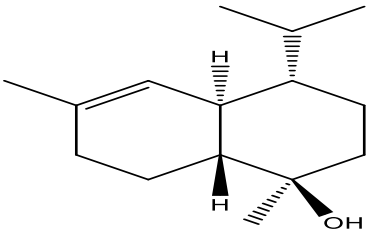
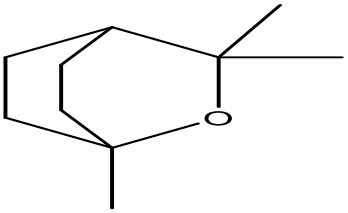
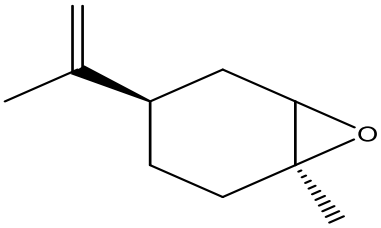
Ethyl Cinnamide	N-(2-hydroxy-2-(4-((3-methylbut-2-en-1-yl)oxy)phenyl)ethyl)cinnamamide		[31, 32]
Aegelin	N-(2-hydroxy-2-(4-methoxyphenyl)ethyl)cinnamamide		[33-35]
Dictamine	4-methoxyfuro[2,3-b]quinoline		[36]
Aegelin	N-(2-hydroxy-2-(4-methoxyphenyl)ethyl)cinnamamide		[37, 38]
Fragrine	4,8-dimethoxyfuro[2,3-b]quinoline		[25, 39]
Eicosapentaenoic acid	(5E,8E,11E,14E,17E)-icosa-5,8,11,14,17-pentaenoic acid		[40, 41]
Omethylhalfordinine	5-(4-((3-methylbut-2-en-1-yl)oxy)phenyl)-2-(pyridin-3-yl)oxazole		[42, 43]
N-4-methoxystyryl cinnamide	methyl (E)-3-(4-methoxyphenyl)acrylate		[26, 44, 45]
Oisopentenyl halfordinol	isopentyl isobutyrate		[46, 47]
N-2-ethoxy-2-(4-methoxy phenyl) ethyl cinnamide	N-(2-ethoxy-2-(4-methoxyphenyl)ethyl)cinnamamide		[45, 48]

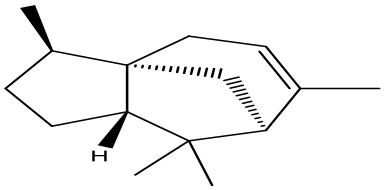
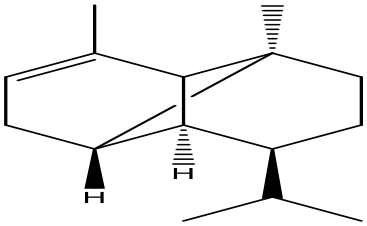
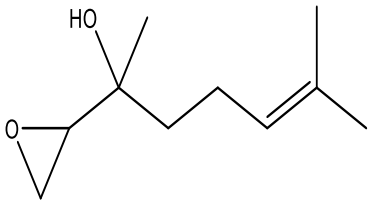
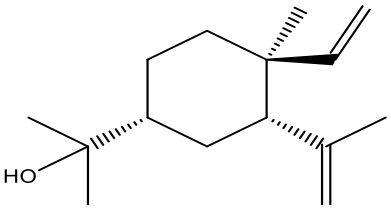
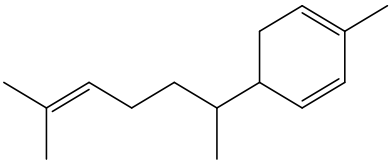
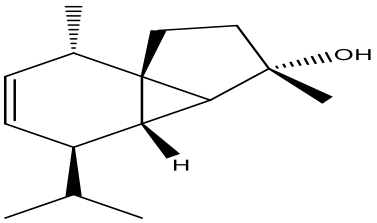
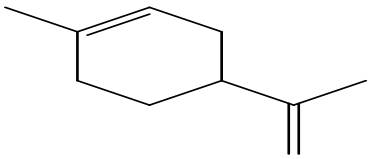
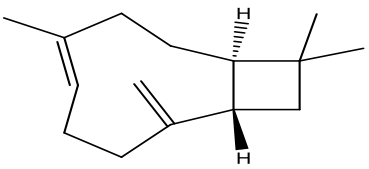
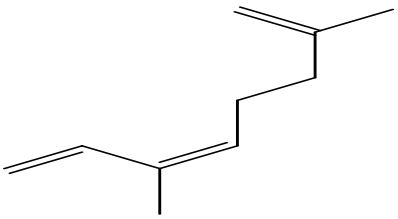
		Marmelosin	9-((3-methylbut-2-en-1-yl)oxy)-7H-furo[3,2-g]chromen-7-one				[33, 49-52]
		Marmin	(R, E)-7-((6,7-dihydroxy-3,7-dimethyloct-2-en-1-yl)oxy)-2H-chromen-2-one				[53-55]
		3marmesin	(S)-2-(2-hydroxypropan-2-yl)-2,3-dihydro-7H-furo[3,2-g]chromen-7-one				[56-58]
		Rutacine	2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-3-(((2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-((((2R,3R,4R,5R,6S)-3,4,5-trihydroxy-6-methyltetrahydro-2H-pyran-2-yl)oxy)methyl)tetrahydro-2H-pyran-2-yl)oxy)-4H-chromen-4-one				[59, 60]
		Marmelosin	9-((3-methylbut-2-en-1-yl)oxy)-7H-furo[3,2-g]chromen-7-one				[49, 61, 62]
		Methyl ether	methoxymethane				[63-65]
2.	Coumarin's	Scoparome	6,7-dimethoxy-2H-chromen-2-one		Chromatographic separation	Prostate cancer, renal cell carcinoma, and leukemia	[66]
		Imperatorin	9-((3-methylbut-2-en-1-yl)oxy)-7H-furo[3,2-g]chromen-7-one				[67, 68]
		Umbelliferone	7-hydroxy-2H-chromen-2-one				[69-71]

		Marmelide	9-((3-methylbut-2-en-1-yl)oxy)-7H-furo[3,2-g]chromen-7-one			[72, 73]
		Mermenol	(E)-7-((2,6-dihydroxy-7-methoxy-7-methyloct-3-en-1-yl)oxy)-2H-chromen-2-one			[74]
		Scopoletin	(E)-7-((2,6-dihydroxy-7-methoxy-7-methyloct-3-en-1-yl)oxy)-2H-chromen-2-one			[75]
		Psoralen	7H-furo[3,2-g]chromen-7-one			[76]
		Alloimperaterin	9-hydroxy-4-(3-methylbut-2-en-1-yl)-7H-furo[3,2-g]chromen-7-one			[77]
		Zanthotaxol	9-hydroxy-7H-furo[3,2-g]chromen-7-one			[78]
		Epoxyauraptan	(E)-7-((3,7-dimethylocta-2,6-dien-1-yl)oxy)-2H-chromen-2-one			[79]
3.	Terpenoid	Alpha phellandrene	5-isopropyl-2-methylcyclohexa-1,3-diene		Hydrodistillation, steam distillation, and solvent extraction	[80]
		3-Carvomenthenol	6-isopropyl-3-methylcyclohex-2-en-1-ol		Immune modulator, antifungal, antiviral, antiparasitic, antispasmodic, antihyperglycemic	[31, 81-83]
		Pentamethylene glycol	pentane-1,5-diol			
		Dipentene	1-methyl-4-(prop-1-en-2-yl)cyclohex-1-ene			

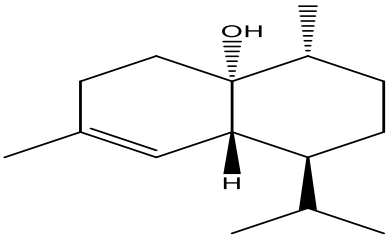
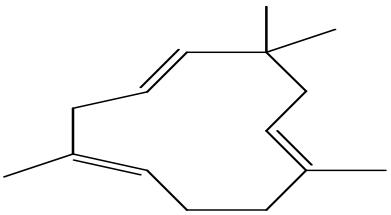
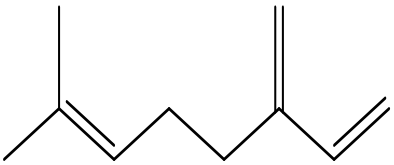
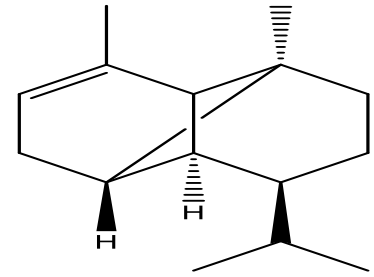
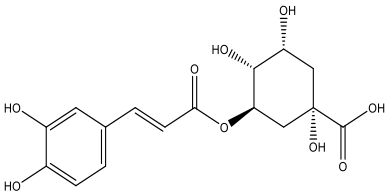
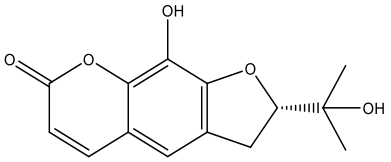
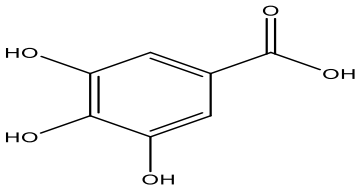
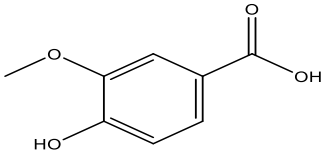
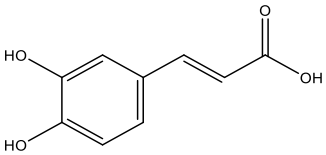
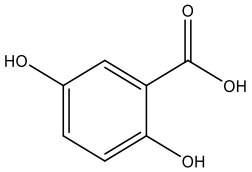
Ocimene	7-methyl-3-methyleneocta-1,6-diene		
Australene	2,6,6-trimethylbicyclo[3.1.1]hept-2-ene		[32]
Delta-3-Carene	3,7,7-trimethylbicyclo[4.1.0]hept-3-ene		[30]
B-ocimene	(E)-3,7-dimethylocta-1,3,6-triene		[84]
Boisvelon	1-(2,3,8,8-tetramethyl-1,2,3,4,5,6,7,8-octahydronaphthalen-2-yl)ethan-1-one		[39]
Licareol	3,7-dimethylocta-1,6-dien-3-ol		[85]
Isoterpinene	1-methyl-4-(propan-2-ylidene)cyclohex-1-ene		
Moslene	1-isopropyl-4-methylcyclohexa-1,4-diene		
Butanoic acid	5-isopropyl-2-methylbicyclo[3.1.0]hexan-1-ol		[32]
Thujen-3en-10-ol	(5-isopropylbicyclo[3.1.0]hex-2-en-2-yl)methanol		

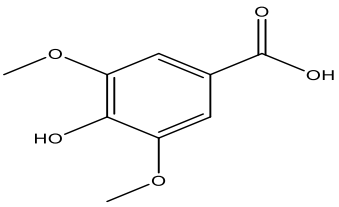
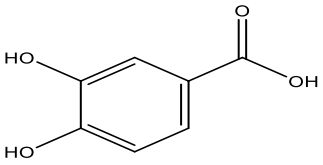
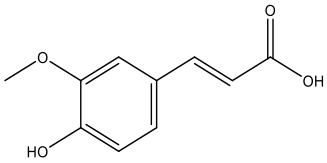
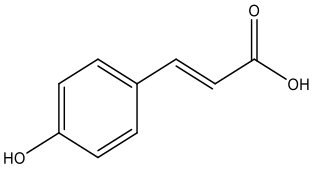
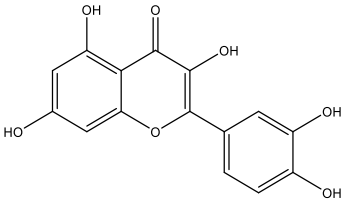
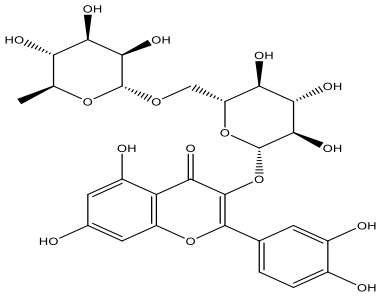
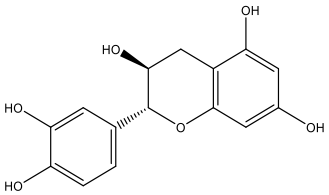
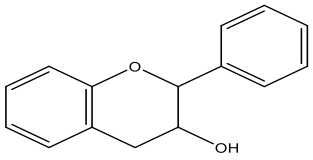
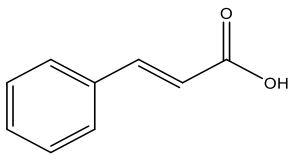
Delta - elemene	(3R,4R)-1-isopropyl-4-methyl-3-(prop-1-en-2-yl)-4-vinylcyclohex-1-ene	
Terpinen-4-ol	1-isopropyl-4-methylcyclohex-3-en-1-ol	
Alpha-cubebene	4-isopropyl-3,7-dimethyl-3a,3b,4,5,6,7-hexahydro-1H-cyclopenta[1,3]cyclopropa[1,2]benzene	
Theta element	(1S,2S)-1-methyl-2-(prop-1-en-2-yl)-4-(propan-2-ylidene)-1-vinylcyclohexane	
Alpha humulene	(1E,4E,8E)-2,6,6,9-tetramethylcycloundeca-1,4,8-triene	
Theta morpholine	1-isopropyl-7-methyl-4-methylene-1,2,3,4,4a,5,6,8a-octahydronaphthalene	
Theta curcumene	1-methyl-4-(6-methylhept-5-en-2-yl)cyclohexa-1,3-diene	
Farnesyl pyrophosphate	(3R,4aS,5R)-4a,5-dimethyl-3-(prop-1-en-2-yl)-1,2,3,4,4a,5,6,7-octahydronaphthalene	
Eudesmane	4a-methyl-1-methylene-7-(prop-1-en-2-yl)decahydronaphthalene	
Sisquiterpenoid	1-methyl-4-(6-methylhepta-1,5-dien-2-yl)cyclohex-1-ene	

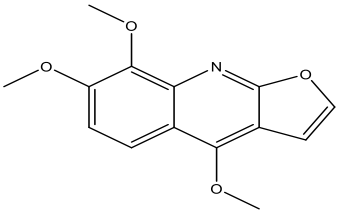
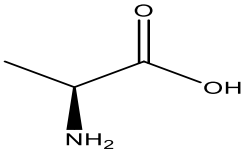
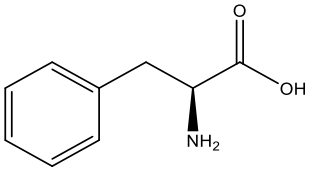
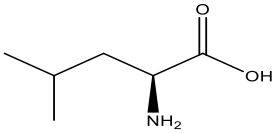
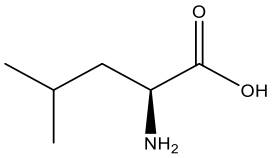
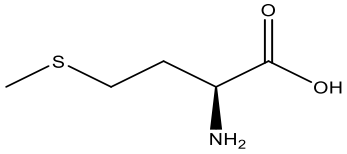
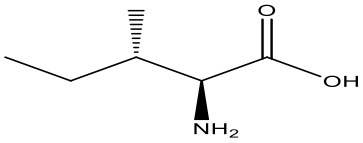
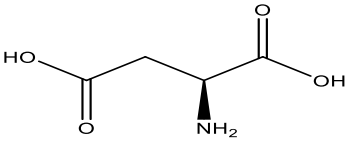
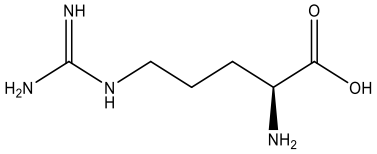
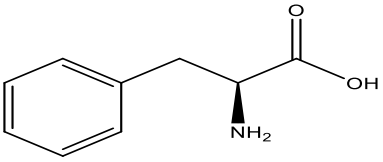
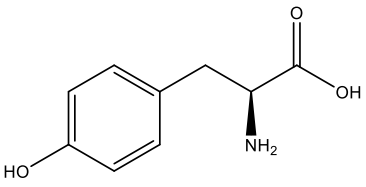
Levomenol	(S)-4-methyl-1-((S)-6-methylhept-5-en-2-yl)cyclohex-3-en-1-ol	
Theta cardinene	1-isopropyl-7-methyl-4-methylene-1,2,3,4,4a,5,6,8a-octahydronaphthalene	
Alpha terphenyl isobutyrate	2-(4-methylcyclohex-3-en-1-yl)propane-2-yl isobutyrate	
Cis, Trans Farnesol	(2E,6E)-3,7,11-trimethyldodeca-2,6,10-trien-1-ol	
2-cis, 6-trans-Farnesol	(2Z,6E)-3,7,11-trimethyldodeca-2,6,10-trien-1-ol	
3z-hexenol	(Z)-hex-1-en-1-ol	
Ethyl hexoic acid	ethyl hexanoate	 [31]
Methyl Perillate	methyl (2E,4E)-5-(benzo[d][1,3]dioxol-5-yl)penta-2,4-dienoate	
Alpha-Cardinol	(1R,4S,4aR,8aR)-4-isopropyl-1,6-dimethyl-1,2,3,4,4a,7,8,8a-octahydronaphthalen-1-ol	 [30]
Eucalyptol	1,3,3-trimethyl-2-oxabicyclo[2.2.2]octane	
Limonene oxide	(1S,4R)-1-methyl-4-(prop-1-en-2-yl)-7-oxabicyclo[4.1.0]heptane	

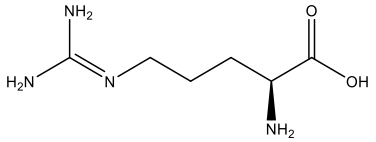
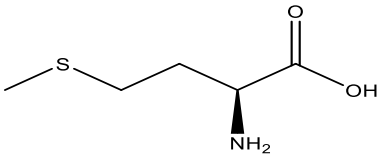
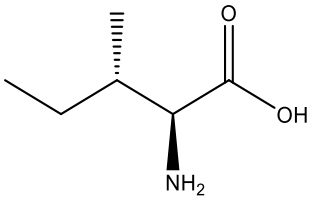
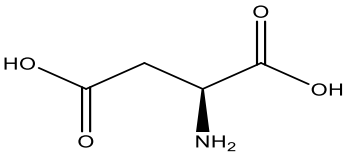
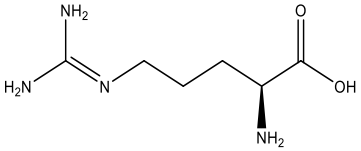
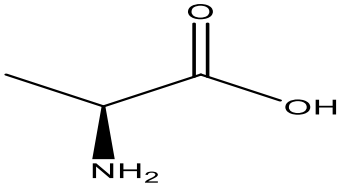
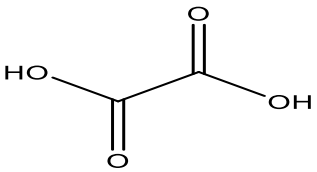
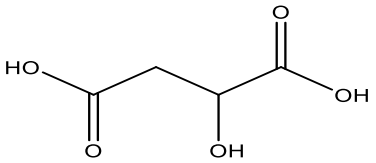
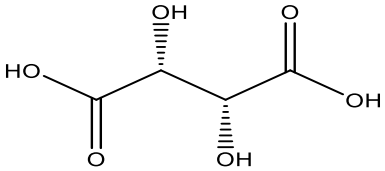
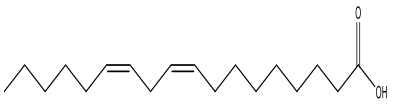
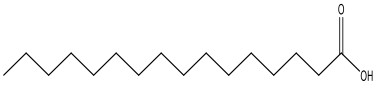
A-cedrene	(3R,3aS,7S,8aS)-3,6,8,8-tetramethyl-2,3,4,7,8,8a-hexahydro-1H-3a,7-methanoazulene	
A-copaene	(1S,6S,7S,8S)-8-isopropyl-1,3-dimethyltricyclo[4.4.0.02,7]dec-3-ene	
Cis-Linalool oxide	6-methyl-2-(oxiran-2-yl)hept-5-en-2-ol	
Elemol	2-((1R,3S,4S)-4-methyl-3-(prop-1-en-2-yl)-4-vinylcyclohexyl)propan-2-ol	
Alpha zingiberene	2-methyl-5-(6-methylhept-5-en-2-yl)cyclohexa-1,3-diene	
Epicubenol	(3S,3bS,4S,7S,7aS)-4-isopropyl-3,7-dimethyl-2,3,3a,3b,4,7-hexahydro-1H-cyclopenta[1,3]cyclopropa[1,2]benzen-3-ol	
Dipentene	1-methyl-4-(prop-1-en-2-yl)cyclohex-1-ene	
Cannabinoid	(1R,9S,E)-4,11,11-trimethyl-8-methylenebicyclo[7.2.0]undec-4-ene	
Alpha ocimene	(Z)-3,7-dimethylocta-1,3,7-triene	

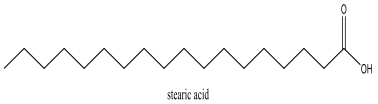
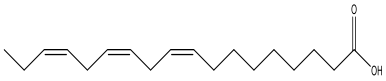
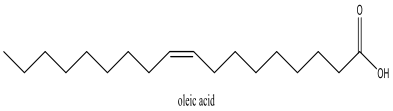
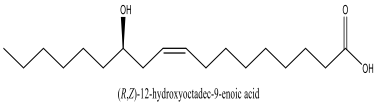
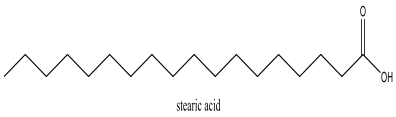
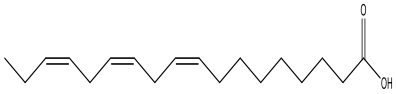
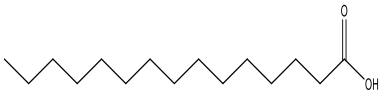
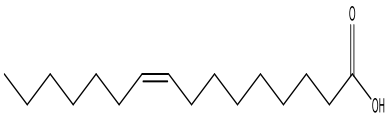
[31]

		Epicubenol	(1S,4R,4aR,8aR)-1-isopropyl-4,7-dimethyl-1,3,4,5,6,8a-hexahydronaphthalen-4a(2H)-ol			
		Alpha humulene	(1E,4E,8E)-2,6,6,9-tetramethylcycloundeca-1,4,8-triene			
		Beta myrcene	7-methyl-3-methyleneocta-1,6-diene			
		Alpha copaene	(1S,6S,7S,8S)-8-isopropyl-1,3-dimethyltricyclo[4.4.0.02,7]dec-3-ene			
		Chlorogenic acid	(1S,3R,4R,5R)-3-(((E)-3-(3,4-dihydroxyphenyl)acryloyl)oxy)-1,4,5-trihydroxycyclohexane-1-carboxylic acid			
		Rutaretin	(S)-9-hydroxy-2-(2-hydroxypropan-2-yl)-2,3-dihydro-7H-furo[3,2-g]chromen-7-one			
4.	Phenolic acid's	Gallic acid	3,4,5-trihydroxybenzoic acid		Column Chromatography	Antioxidant's
		Vanillic acid	4-hydroxy-3-methoxybenzoic acid			
		Caffeic acid	(E)-3-(3,4-dihydroxyphenyl)acrylic acid			
		Gentisic acid	2,5-dihydroxybenzoic acid			

		Syringic acid	4-hydroxy-3,5-dimethoxybenzoic acid				
		Procatechuic acid	3,4-dihydroxybenzoic acid				
		Ferulic acid	(E)-3-(4-hydroxy-3-methoxyphenyl)acrylic acid				
		P- coumaric Acid	(E)-3-(4-hydroxyphenyl)acrylic acid				
5.	Flavonoid's	Quercetin	2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxy-4H-chromen-4-one		Chromatographic techniques	anticancer, antioxidant, anti-inflammatory, and antiviral properties	[10]
		Rutin	2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-3-(((2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-((((2R,3R,4R,5R,6S)-3,4,5-trihydroxy-6-methyltetrahydro-2H-pyran-2-yl)oxy)methyl)tetrahydro-2H-pyran-2-yl)oxy)-4H-chromen-4-one				[18]
		Catechin	(2R,3S)-2-(3,4-dihydroxyphenyl)chromane-3,5,7-triol				
		Flavan-3-ol	2-phenylchroman-3-ol				
6.	Carotenoid's	Skimminianine	2-phenylchroman-3-ol		Chromatography	Antioxidants, immunomodulator	

		4, 7, 8-trimethoxyfuro-quinoline	4,7,8-trimethoxyfuro[2,3-b]quinoline				
		Alanine	(2S)-2-aminopropanoic acid				
		Phenyl alanine	(2S)-2-amino-3-phenylpropanoic acid				
		Tyrosine	L-tyrosine				
7.	Tannin's	Leucine	(2S)-2-amino-4-methylpentanoic acid		Extraction technique	Antidote, antiseptic and astringent	[14]
		Methionine	(2S)-2-amino-4-methylsulfanylbutanoic acid				
		Isoleucine	(2S,3S)-2-amino-3-methylpentanoic acid				
		Aspartic acid	(2S)-2 -aminobutanedioic acid				
		Arginine	(S) - 2-Amino - 5-guanidinopentanoic acid				
		Phenyl alanine	(2S) – 2 –amino - 3-phenylpropanoic acid		Ion exchange, metal affinity, and gel filtration chromatography	Body proteins, neurotransmitter's, and Hormones synthesis	
8.	Amino acid's	Tyrosine	(2S)-2-amino-3-(4-hydroxyphenyl)propanoic acid				

		Leucine	(S)-2-amino-5-((diaminomethylene)amino)pentanoic acid			
		Methionine	(2S)-2-amino-4-methylsulfanylbutanoic acid			
		Isoleucine	(2S,3S)-2-amino-3-methylpentanoic acid			[25]
		Aspartic acid	(2S)-2-aminobutanedioic acid			
		Arginine	(S)-2-amino-5-((diaminomethylene)amino)pentanoic acid			
		Alanine	(2S)-2-aminopropanoic acid			
9.	Organic acid's	Oxalic acid	Oxalic acid		anion exchange, ion exclusion, and reversed-phase high-performance liquid chromatography	Antimicrobials, preservatives, and sanitizers
		Malic acid	2-hydroxysuccinic acid			
		Tartaric acid	(2R,3R)-2,3-dihydroxysuccinic acid			
10.	Fatty acid's	Linoleic	(9Z,12Z)-octadeca-9,12-dienoic acid		Low-temperature crystallization, distillation, and precipitation techniques	Gene regulation, membrane component formation, and source of energy
		Palmitic	Hexadecanoic acid			

Stearic	Octadecanoic acid	
Linolenic acid	(9Z,12Z,15Z)-octadeca-9,12,15-trienoic acid	
Oleic acid	(Z)-octadec-9-enoic acid	
Ricinoleic acid	(R, Z)-12-hydroxyoctadec-9-enoic acid	
Stearic acid	Octadecanoic acid	
Linolenic acid	(9Z,12Z,15Z)-octadeca-9,12,15-trienoic acid	
Tetradecanoic acid	tetradecanoic acid	
Pentadecanoic acid	pentadecanoic acid	
Palmitoleic acid	(Z)-hexadec-9-enoic acid	

[62]

Medicinal and pharmacological properties

Anticancer activity

Studies suggested that certain compounds found in bael, including alkaloids and essential oils, may exhibit cytotoxic effects on cancer cells [19]. *A. marmelos* extract shows significant inhibition on MCF 7 and MDAMB 231 breast cancer cell lines [6]. These compounds could interfere with the growth and division of cancer cells, leading to their destruction **(Figure 3)** [19].

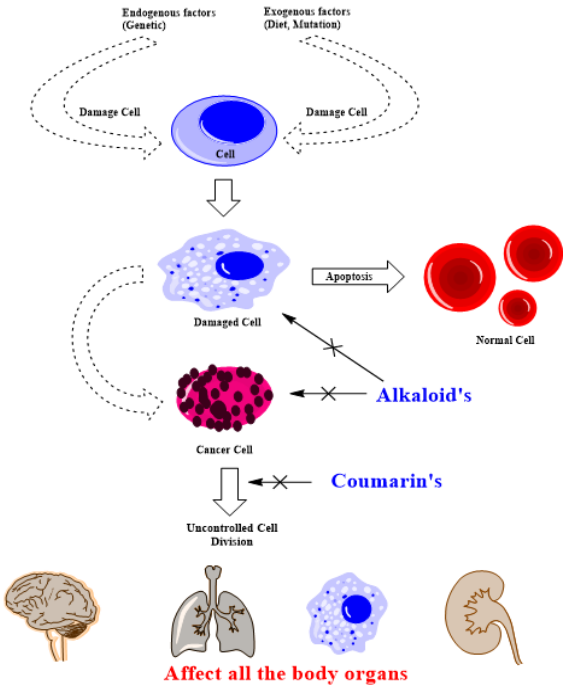


Figure 3. Anticancer effect of *AM*

Antidiabetic activity

Diabetes mellitus is a common metabolic disorder [72, 86]. *A. marmelos* hydro-alcoholic extract helps to reduce the blood sugar level as well as significantly increase the blood insulin and liver glycogen in diabetic rats [10, 42].

Anti-ulcer activity

Currently, due to lifestyle gastric disorders are common, Researchers reported that the methanolic extract of bael is highly effective for reducing gastrointestinal ulcers [35, 47].

Antimicrobial activity

The antibacterial activity of the different *A. marmelos* extracts were tested quinine compound was identified as possessing good antibacterial activity [66]. Researchers found that extract is highly effective as compared to other allopathic preparations against gram-positive and negative bacteria **(Figure 4)** [18, 55].

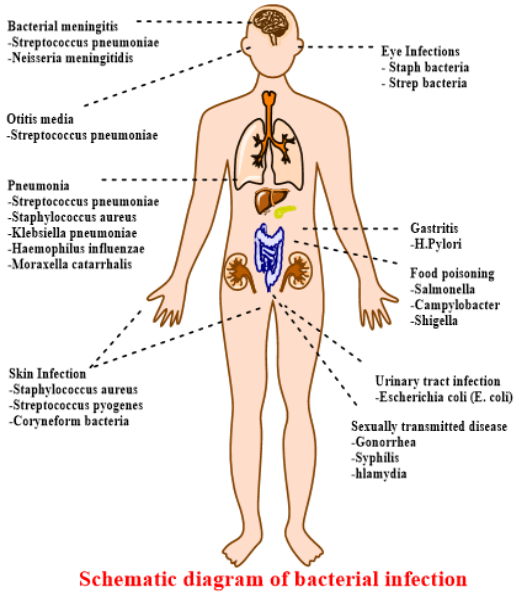


Figure 4. Antibacterial effect of *AM*

Antioxidant activity

Oxidative stress is induced due to physical, chemical, environmental as well as biological factors which cause the generation of free radicals [51]. *A. marmelos* phytoconstituents play a crucial role in free radical scavenging, these alteration returns the free radical to normal levels which reveals the antioxidant activity of bael extract [67, 83].

Anti-hyperlipidemic activity

Literature surveys reveal that bael extract induces the utilization of elevated fatty acids and their types [74]. As a result, lower levels of fatty acids were formed which is an important channel for consumption of higher glucose molecules [58].

Radioprotective action

In recent times radiotherapy has been one of the important causes of cancer because of its free radical formation-inducing property. *A. marmelos* extract was reported for the free radical scavenging of radiation-induced free radicals [73]. The radioprotective activity was studied in Swiss albino rats that were given a lot of intraperitoneal single doses of the extract [74].

Antiviral activity

The ability of different varieties of fungi to grow is tested by the separated volatile oil from *A. marmelos* [72]. The essential oil fully stopped all fungi from generating spores at a dosage of 0.05%. Around 75% and 90% of the fungus are significantly suppressed at 0.03%- 0.04%, respectively **(Figure 5)** [66].

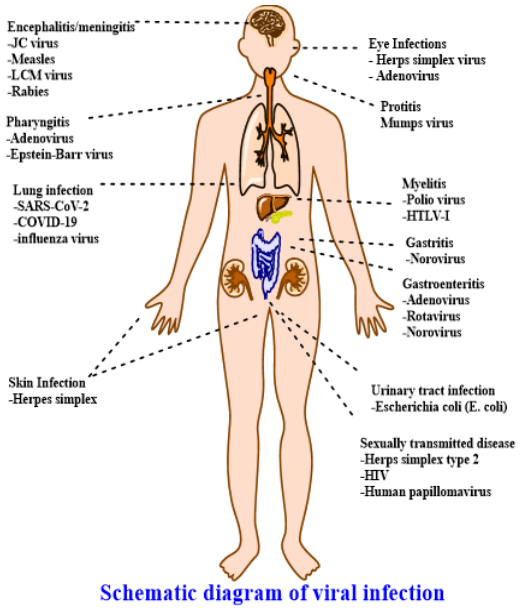


Figure 5. Antiviral of *A. marmelos*

Conclusion

The present study suggested that the therapeutic potential of *AM* and the phytoconstituents may be utilized to develop unique formulations for the management, mitigation as well as prevention of cancer, diabetes mellitus, and other microbial diseases [47]. Numerous ethnobotanical uses of *AM* have been documented in the past. Unfortunately, the majority of substances still need to be carefully examined to look into new lead molecules or pharmacophores. A few bioactive compounds' processes have also so far been identified. To determine the pathophysiology as well as the pharmacology of various phytochemicals with the efficacy of *AM* pharmacological properties, extensive research is required [1].

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