Natural products isolated from Casimiroa

by Alfinda Novi Kristanti

Review Article

Khun Nay Win Tun, Nanik Siti Aminah*, Alfinda Novi Kristanti, Hnin Thanda Aung, Yoshiaki Takaya

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Abstract: About 140 genera and more than 1,600 species belong to the Rutaceae family. They grow in temperate and tropical zones on both hemispheres, as trees, shrubs, and herbs. *Casimiroa* is one of the genera constituting 13 species, most of which are found in tropical and subtropical regions. Many chemical constituents have been derived from this genus, including quinoline alkaloids, flavonoids, coumarins, and *N*-benzoyltyramide derivatives. This article reviews different studies carried out on aromatic compounds of genus *Casimiroa*; their biological activities; the different skeletons of coumarins, alkaloids, flavonoids, and others; and their characteristic NMR spectral data.

Keywords: aromatic compounds, *Casimiroa*, NMR spectral data, Rutaceae

1 Introduction

Natural products, including plants, animals, microorganisms, and marine organisms, have been used by humans as medicines to prevent and treat diseases since ancient times. According to historical records, the use of plants as medicines is an traditional practice and started with human interaction with the environment [1–5]. Both in the developing and developed countries, people rely on herbal medicine because of fewer side effects [6,7]. There are many plants used in folk medicine. Many plant-based bioactive substances have been isolated, characterized, and used in pure form or as suitable derivatives for the therapeutic purpose [8,9]. The World Health Organization estimates that 80% of the world's population rely on traditional medicines for their primary health care needs [10]. The therapeutic potential of plants lies in chemical substances that produce a definite physiological action on man and animals. The key bioactive compounds in plants are produced as secondary metabolites [11,12].

Plants of *Casimiroa* belong to the Rutaceae family, which grows as tree in the tropical and subtropical areas of Central America and Mexico, the Caribbean, the Mediterranean region, India, Southeast Asia, South Africa, Australia, and New Zealand. This genus constitutes 13 species, and most of them, both wild and cultivated, are found in Mexico. The best-known species is *Casimiroa edulis* La Llave, also called "sapote blanco," "Mexican apple," "white sapote," "*Casimiroa*," and "sapote blance" by native people. Its fruit are edible [13,14]. Traditionally, the fruit and leaves of *Casimiroa* species are used to treat anxiety, as sedatives, and to treat dermatological conditions [15]. The pharmacological studies of an aqueous extract and alcohol extracts of the seeds and leaves of *C. edulis* exhibited the cardiovascular, anticonvulsant, sedative activities, anti-inflammatory, antimutagenic, diuretic activities, hypnotic, antihypertension, diuretic, anti-inflammatory muscle relaxant, and contractile properties. The pharmacological activities of the bioactive compounds from *Casimiroa* were also reported. Several species of this genus have been reported to possess interesting secondary metabolites. Among the major constituents of *Casimiroa* species are alkaloids, flavonoids, coumarins, limonoids, and *N*-benzoyltyramide derivatives [16–38]. The structures of the isolated compounds were elucidated based on the spectroscopic data, including NMR spectroscopy. This article also includes a review of characteristic NMR data of various classes of compounds from this genus.

*** Corresponding author: Nanik Siti Aminah,** Department of Chemistry, Faculty of Science and Technology, Universitas Airlangga, Komplek Kampus C UNAIR, Jl. Mulyorejo, Surabaya, Indonesia, e-mail: nanik-s-a@fst.unair.ac.id, tel: +62-31-5936501, fax: +62-31-5936502
Khun Nay Win Tun: Department of Chemistry, Faculty of Science and Technology, Universitas Airlangga, Komplek Kampus C UNAIR, Jl. Mulyorejo, Surabaya, Indonesia; Department of Chemistry, Taunggyi University, Taunggyi, Myanmar
Alfinda Novi Kristanti: Department of Chemistry, Faculty of Science and Technology, Universitas Airlangga, Komplek Kampus C UNAIR, Jl. Mulyorejo, Surabaya, Indonesia
Hnin Thanda Aung: Department of Chemistry, Mandalay University, Mandalay, Myanmar
Yoshiaki Takaya: Faculty of Pharmacy, Meijo University, 150 Yagotoyama, Tempaku, Nagoya, 468-8503, Japan

Table 1: Pharmacological properties of compounds obtained from *Casimiroa* species

Compound (Cp)	Biological activities	Plant	Part used	Ref.
Umbelliferone (**1**)	Anticoagulant	*C. edulis*	Leaves	[25]
Esculetin (**2**)	Anticoagulant	*C. edulis*	Leaves	[25]
Herniarin (**3**)	Vasodilation and radical scavenging	*C. edulis* and *C. pubescens*	Seeds	[31]
3-(1′,1′-Dimethyl-allyl)-herniarine (**4**)	–	*C. pubescens*	Roots	[36]
Auraptene (**5**)	–	*C. pubescens*	Roots	[36]

2 Plant description

Plant descriptions of the best known species from *Casimiroa* are presented as follows:

Kingdom	Plantae
Order	Sapindales
Family	Rutaceae
Genus	*Casimiroa*
Species	*C. edulis*
Botanical name	*Casimiroa edulis* La Llave
English name	White sapote
Myanmar name	Tha-kyar-tee

C. edulis is 4.6–18.3 m high. Flowers are small, odorless, and pale green to cream color with five sepals, petals, and stamens. Fruits are round, ovary, or ovoid and golden-yellow when ripe. The leaflets are ovate and 4.5–12 cm long and 1–5 cm wide, with cuneate base, subserrate margins, bright green, glabrous or with scattered pubescence on the veins, pinnate vennation, and anastomising at the margins. The apex is acuminate.

2.1 *Casimiroa tetrameria*

C. tetrameria is about 50 ft height with dense, white, furry underside leaves. The small flowers grow in big groups and blossom many times a year, with fruit ripening after 6–8 months. This plant is originally from Southern Mexico, and it is not grown commercially.

Table 2: ^{13}C and ^{1}H NMR (δ, ppm) chemical shift data of simple coumarins isolated from genus *Casimiroa*

Carbon no.	Cp 1 [62]		Cp 2 [64]		Cp 3 [63]		Cp 4 [36]		Cp 5 [65]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C (prediected)	δ_H	δ_C	δ_H
2	162.9	–	162.9	–	161.1	–	159.7	–	161.4	–
3	113.7	6.16	111.0	6.16	112.5	6.25	131.1	–	113.0	6.23
4	145.0	7.77	144.7	7.77	143.3	7.62	138.0	7.54	143.6	7.61
4a	112.2	–	111.3	–	112.5	–	112.5	–	112.5	–
5	129.6	7.39	111.5	6.74	128.7	7.37	129.8	7.36	128.8	7.34
6	113.7	6.77	143.2	–	113.0	6.85	111.0	6.83	113.3	6.83
7	162.0	–	150.8	–	162.8	–	160.2	–	162.2	–
8	102.8	6.71	102.2	6.93	100.8	6.82	100.6	6.83	101.7	6.80
8a	156.2	–	149.1	–	155.8	–	156.9	–	155.9	–
7 O-Me	–	–	–	–	55.7	3.86	55.8	3.88	–	–
1′	–	–	–	–	–	–	40.3	–	65.6	4.58
2′	–	–	–	–	–	–	145.6	6.19	118.5	5.45
3′	–	–	–	–	–	–	112.6	5.09, 5.13	142.5	–
4′	–	–	–	–	–	–	–	–	39.6	2.10
5′	–	–	–	–	–	–	–	–	26.3	2.12
6′	–	–	–	–	–	–	–	–	123.7	5.06
7′	–	–	–	–	–	–	–	–	132.1	–
8′	–	–	–	–	–	–	–	–	25.8	1.65
9′	–	–	–	–	–	–	–	–	17.8	1.59
10′	–	–	–	–	–	–	–	–	16.9	1.75
1′-Me-a	–	–	–	–	–	–	26.2	1.50	–	–
1′-Me-b	–	–	–	–	–	–	26.2	1.50	–	–

Table 3: Pharmacological properties of compounds isolated from various *Casimiroa* species

Compound (Cp)	Biological activities	Plant	Part used	Ref.
Xanthotoxol (**6**)	Anticoagulant	*C. edulis*	Leaves	[25]
Bergapten (**7**)	Antidiabetic	*C. edulis*	Stem bark	[38]
5-Methoxy-8-hydroxypsoralen (**8**)	–	*C. edulis*	Seeds	[66]
Isopimpinellin (**9**)	Antidiabetic and Antimutagenic	*C. edulis* and *C. pubescens*	Seeds	[24,33,38]
Imperatorin (**10**)	Anticoagulant, vasodilation, and radical scavenging	*C. edulis* and *C. pubescens*	Seeds	[25,31]
(*R,S*)-8-[(6,7-Dihydroxy-3,7-dimethyl-2-octenyl)oxy]psoralen (**11**)	Antimutagenic	*C.edulis*	Seeds	[24]
8-Geranyloxypsoralen (**12**)	Vasodilation and radical scavenging	*C. edulis* and *C. pubescens*	Seeds & leaves	[31]
8-(3′-Hydroxymethyl-but-2-enyloxy)-psoralen acetate (**13**)	Adipogenesis	*C. edulis* & *C. pringlei*	Leaves	[29]
Phellopterin (**14**)	Antimutagenic	*C. edulis*	Seeds	[24]
(*R,S*)-5-Methoxy-8-[(6,7-dihydroxy-3,7-dimethyl-2-octenyl)oxy] psoralen (**15**)	Antimutagenic	*C. edulis*	Seeds	[24]
5-Methoxy-8-geranyloxypsoralen (**16**)	–	*C. edulis*	Seeds	[66]
8-(3′-Hydroxymethyl-but-2-enyloxy)-5-methoxypsoralen acetate (**17**)	Adipogenesis	*C. edulis*	Leaves	[29]
5-Methoxy-8-(3″-hydroxymethyl-but-2″-enyloxy)-psoralen (**18**)	–	*C. tetrameria*	Leaves	[30]
5-Methoxy-8-(4′-acetoxy-3′-methyl-but-2-enyloxy) psoralen (**19**)	Solid tumor selective cytotoxicity	*C. tetrameria*	Seeds & leaves	[33]

Table 4: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of furanocoumarins isolated from genus *Casimiroa*

Carbon no.	Cp 6 [67]		Cp 7 [38]		Cp 8 [68]		Cp 9 [69]		Cp 10 [70]		Cp 11 [24]		Cp 12 [70]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
2	159.6	–	161.2	–	160.91	–	160.4	–	160.6	–	160.7	–	160.5	–
3	114.7	6.3	112.6	6.28	113.54	6.23	112.8	6.26	114.7	6.30	114.7	6.37	114.7	6.34
4	145.41	8.0	139.2	8.16	140.15	8.10	139.3	8.10	144.4	7.70	144.5	7.78	144.3	7.74
4a	116.4	–	106.5	–	108.11	–	107.6	–	116.5	–	116.5	–	116.4	–
5	110.3	no data	149.6	–	150.34	–	144.3	–	113.2	7.29	113.4	7.38	113.2	7.34
5-OMe	–	–	60.1	4.27	62.31	4.25	61.6	4.16	–	–	–	–	–	–
6	125.7	–	112.7	–	115.20	–	114.8	–	125.9	–	125.9	–	125.8	–
7	147.21	–	158.4	–	158.61	–	150.0	–	148.6	–	148.7	–	148.7	–
8	130.2	–	93.9	7.14	143.12	–	128.2	–	131.7	–	131.6	–	131.5	–
8-OMe			–	–	–	–	60.8	4.14	–	–	–	–	–	–
8a	139.81	–	152.7	–	152.80	–	143.7	–	143.8	–	143.9	–	143.9	–
2′	145.03	7.4	144.8	7.60	145.18	7.59	145.1	7.61	146.7	7.62	146.7	7.70	146.6	7.66
3′	106.87	6.95	105.0	7.02	105.62	6.99	105.1	6.99	106.7	6.75	106.7	6.82	106.7	6.79
1″	–	–	–	–	–	–	–	–	70.2	4.94	70.1	5.03	70.1	5.01
2″	–	–	–	–	–	–	–	–	119.8	5.54	120.1	5.67	119.4	5.57
3″	–	–	–	–	–	–	–	–	139.8	–	142.8	–	143.2	–
4″	–	–	–	–	–	–	–	–	18.2	1.65	36.4	2.27, 2.13	39.5	1.98
5″	–	–	–	–	–	–	–	–	25.9	1.67	29.2	1.55, 1.42	26.3	1.99
6″	–	–	–	–	–	–	–	–	–	–	77.7	3.27	123.7	4.98
7″	–	–	–	–	–	–	–	–	–	–	73.0	–	131.7	–
8′	–	–	–	–	–	–	–	–	–	–	26.4	1.17	25.6	1.61
9″	–	–	–	–	–	–	–	–	–	–	23.0	1.13	17.6	1.54
10″	–	–	–	–	–	–	–	–	–	–	16.5	1.71	16.5	1.67
Acetyl-Me	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Acetyl(C=O)	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 5: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of furanocoumarins isolated from genus *Casimiroa*

Carbon no.	Cp 13 [29]		Cp 14 [71]		Cp 15 [24]		Cp 16 [72]		Cp 17 [29]		Cp 18 [30]		Cp 19 [33]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
2	160.43	–	160.5	–	160.7		160.84	–	160.42		160.7	–	160.4	–
3	114.83	7.77	112.8	6.27	112.7	6.28	113.04	6.27	112.91	6.28	112.82	6.27	112.9	6.27
4	144.27	6.38	139.4	8.12	139.5	8.13	139.71	8.11	139.55	8.12	139.7	8.11	139.3	8.10
4a	116.54	–	107.5	–	107.5	–	107.78		107.61	–	107.7	–	107.6	–
5	113.81	7.37	144.3	–	144.5	–	144.67	–	144.26	–	150.7	–	144.5	–
5-OMe	–	–	60.7	4.17	60.7	4.18	61.02	4.16	60.79	4.18	60.8	4.16	60.8	4.16
6	125.95	–	114.5	–	114.5	–	114.73	–	114.61	–	114.6	–	114.6	–
7	148.32	–	150.8	–	150.9	–	151.18	–	150.57	–	Abs	–	150.5	–
8	131.39	–	126.8	–	126.7	–	126.99	–	136.51	–	Abs	–	126.6	–
8-OMe	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8a	143.67	–	144.3	–	144.4	–	144.70		125.63	–	143.1	–	144.2	
2′	146.76	7.69	145.1	7.62	145.1	7.63	145.34	7.61	145.16	7.64	145.3	7.61	145.1	7.60
3′	106.76	6.82	105.0	6.98	105.1	7.00	105.36	6.98	105.12	6.99	105.3	6.98	105.1	6.97
1″	69.12	5.09	70.4	4.83	70.3	4.88	70.53	4.87	69.36	4.91	69.3	4.86	69.3	4.90
2″	125.13	5.86	119.8	5.59	120.2	5.66	119.70	5.58	125.27	5.86	122.2	5.71	125.2	5.84
3″	136.57	–	139.7	–	142.6	–	143.41	–	136.51		Abs	–	136.5	
4″	62.79	4.66	25.8	1.73	36.4	2.26, 2.12	39.85	1.99	62.78	4.66	21.5	1.85	21.4	1.79
5″	21.42	1.81	18.0	1.69	29.2	1.55, 1.38	26.63	1.99	21.41	1.80	61.8	δ 4.24	62.8	4.62
6″	–	–	–	–	77.6	3.24	124.07	5.01	–	–	–	–	–	–
7″	–	–	–	–	73.0	–	131.98	–	–	–	–	–	–	–
8′	–	–	–	–	26.4	1.17	17.92	1.56	–	–	–	–	–	–
9″	–	–	–	–	23.0	1.13	25.93	1.64	–	–	–	–	–	–
10″	–	–	–	–	16.3	1.68	16.77	1.66	–	–	–	–	–	–
Acetyl-Me	20.83	2.04	–	–	–	–	–	–	20.84	2.03	–	–	20.9	2.02
Acetyl(C═O)	170.85	–	–	–	–	–	–		170.84	–	–		170.8	–

Table 6: Pharmacological properties of compounds isolated from *Casimiroa* species

Compound (Cp)	Biological activities	Plant	Part used	Ref.
Proline (**20**)	Cardiovascular	*C. edulis*	Seeds	[35]
N-Methylproline (**21**)	Cardiovascular	*C. edulis*	Seeds	[35]
N-Monomethylhistamine (**22**)	Cardiovascular	*C. edulis*	Seeds	[35]
N,N-Dimethylhistamine (**23**)	Cardiovascular	*C. edulis*	Seeds	[35]
Synephrine acetonide (**24**)	Cardiovascular	*C. edulis*	Seeds	[35]
γ-Amino-butyric acid (**25**)	Cardiovascular	*C. edulis*	Seeds	[35]
Casimiroedine (**26**)	Cardiovascular	*C. edulis*	Seeds	[35]

Table 7: Pharmacological properties of compounds obtained from *Casimiroa* species

Compound (Cp)	Biological activities	Plant	Part used	Ref.
4-Methoxy-1-methyl-2(1*H*)-quinolinone (**27**)	Antimutagenic	*C. edulis*	Seeds	[24]
Edulitine (**28**)	–	*C. edulis*	Trunk & root bark	[23]
Casimiroin (**29**)	Antimutagenic	*C. edulis*	Seeds	[24]
Dictamnine (**30**)	–	*C. edulis*	Bark	[23]
γ-Fagarine (**31**)	Antimutagenic	*C. edulis*	Seeds & bark	[23,24]
Skirnmianine (**32**)	–	*C. edulis*	Bark	[23]

Table 8: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of alkaloid isolated from genus *Casimiroa*

Carbon no.	Cp 27 [81]	
	δ_C	δ_H
1-NMe	29.03	3.70
2	163.82	–
3	96.49	6.06
4	162.64	–
4-OMe	55.79	3.97
4a	116.50	–
5	131.18	7.35
6	121.61	7.60
7	123.34	7.24
8	114.01	7.99
8a	139.75	–

2.2 *Casimiroa pringlei*

C. pringlei is a small tree found in central Mexico, which is about 4 m tall. There were no other literature references found. There were no reports about plant descriptions for other species.

3 Chemical constituents

Recently, many chemical constituents have been derived from *Casimiroa*. These compounds can be classified into four groups: coumarins, alkaloids, flavonoids, and four *N*-benzoyltyramide derivatives. Name of the compounds and the corresponding plant sources are presented in Tables 1, 3, 6, 7, 11, 14, and 18.

Table 9: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of alkaloid isolated from genus *Casimiroa*

Carbon no.	Cp 29 [24]	
	δ_C	δ_H
1-NMe	29.1	3.84
2	164.1	–
3	94.6	5.89
4	162.7	–
4-OMe	55.8	3.91
5	118.0	7.53
6	104.3	6.78
7	149.9	–
8	133.5	–
9	101.0	6.04
4a	113.0	–
8a	126.5	–

Table 10: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of furoquinoline alkaloids isolated from genus *Casimiroa*

Carbon no.	Cp 30 [82]		Cp 31 [83]		Cp 32 [84]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
2	168.9	–	163.2	–	164.4	–
3	103.7	–	103.9	–	102.0	–
4	157.0	–	156.9	–	157.2	–
4a	119.0	–	119.7	–	114.9	–
4-OMe	59.1	4.45	59.0	4.42	58.9	4.42
5	122.4	8.27	114.1	7.82	118.2	8.01
6	123.8	7.45	123.4	7.34	112.1	7.23
7	129.6	7.68	107.5	7.04	152.2	–
7-OMe	–	–	–	–	56.8	4.03
8	128.0	8.01	154.6	–	142.0	–
8a	145.9	–	137.5	–	141.5	–
8-OMe	–	–	56.0	4.06	61.7	4.12
2′	143.7	7.08	143.9	7.62	143.0	7.58
3′	104.8	7.69	104.5	7.05	104.6	7.03

4 Coumarins

Coumarin, being one of the members of the benzopyrone family, comprises a large group of compounds. More than 1,300 naturally occurring coumarins have been isolated from plants, bacteria, and fungi. It was first isolated from tonka bean and is reported in about 150 different species, distributed over nearly 30 different families, of which a few important ones are Rutaceae, Umbelliferae, Orchidaceae, Leguminosae, Labiatae, Clusiaceae, Guttiferae, Caprifoliaceae, Oleaceae, Nyctaginaceae, and Apiaceae. Coumarin is also found in fruits, green tea, and other foods such as chicory. Natural coumarins are mainly classified into six types based on their chemical structures. They are simple coumarins, furano coumarins, dihydro-furano coumarins, pyrano coumarins (linear and angular types), phenyl coumarins, and bicoumarins [39–41]. Coumarin is a plant-derived natural product known for its pharmacological properties such as anti-inflammatory [42,43], antibacterial [42], anticoagulant [44], antifungal [45,46], antiviral [47,48], anticancer [49–51], antidiabetic [52,53], antihypertensive [54], anticonvulsant [55], antioxidant [56–59], antimicrobial [60], and neuroprotective properties [61]. *Casimiroa* is the abundant source of coumarins. Simple coumarins, umbelliferone (**1**), esculetin (**2**), herniarin (**3**), 3-(1′,1′-dimethyl-allyl)-herniarine (**4**), and auraptene (**5**) were isolated from various parts (leaves,

Table 11: Pharmacological properties of quinolinone alkaloids obtained from *Casimiroa* species

Compound (Cp)	Biological activities	Plant	Part used	Ref.
1-Methyl-2-phenyl-4-quinolone (**33**)	Solid tumor selective cytotoxicity	*C. tetrameria*	Seeds	[33]
Edulein (**34**)	–	*C. edulis*	Trunk & root bark	[23]
5-Hydroxy-1-methyl-2-phenyl-4-quinolone (**35**)	Antimutagenic	*C. edulis*	Seeds	[24]
5,6-Dimethoxy-2-(3′-methoxyphenyl)-1*H*-quinolin-4-one (**36**)	–	*C. edulis*	Leaves	[28]
5,6-Dimethoxy-2-(3′,4′-dimethoxyphenyl)-1*H*-quinolin-4-one (**37**)	–	*C. edulis*	Leaves	[28]
5,6-Dimethoxy-2-(2′,5′,6′-tri-methoxyphenyl)-1*H*-quinolin-4-one (**38**)	Antihypertensive	*C.edulis*	Leaves & Fruits	[27,28]
5,8-Dimethoxy-2-(3′-methoxy-phenyl)-3-propyl-1*H*-quinolin-4-one (**39**)	Antihypertensive	*C. edulis*	Fruits	[27]
5,8-Dimethoxy-2-(3′,4′-di-methoxyphenyl)-3-propyl-1*H*-quinolin-4-one (**40**)	Antihypertensive	*C. edulis*	Fruits	[27]
2-(2′-Hydroxy-4′-methoxy-phenyl)-5,8-dimethoxy-3-propyl-1*H*-quinolin-4-one (**41**)	Antihypertensive	*C. edulis*	Fruits	[27]

seeds, and roots) of *C. edulis* and *Casimiroa pubescens* [25,31,36]. Fourteen furocoumarins, xanthotoxol (**6**), bergapten (**7**), 5-methoxy-8-hydroxypsoralen (**8**), isopimpinellin (**9**), imperatorin (**10**), (*R*,*S*)-8-[(6,7-dihydroxy-3,7-dimethyl-2-octenyl)oxy]psoralen (**11**), 8-geranyloxypsoralen (**12**), 8-(3′-hydroxymethyl-but-2-enyloxy)-psoralen acetate (**13**), phellopterin (**14**), (*R*,*S*)-5-methoxy-8-[(6,7-dihydroxy-3,7-dimethyl-2-octenyl)oxy]psoralen (**15**), 5-methoxy-8-geranyloxypsoralen (**16**), 8-(3′-hydroxymethyl-but-2-enyloxy)-5-methoxypsoralen acetate (**17**), 5-methoxy-8-(3″-hydroxymethyl-but-2″′-enyloxy)-psoralen (**18**), and 5-methoxy-8-(4′-acetoxy-3′-methyl-but-2-enyloxy) psoralen (**19**) were also identified from various parts (leaves, stem bark, and seeds) of *C. edulis*, *C. pubescens*, and *C. tetrameria* [24,25,29–31,33,38,66]. The structures of various coumarin compounds are shown in Figure 1 and 2, and their NMR (^{1}H NMR and ^{13}C NMR) data are listed in Tables 2, 4, and 5.

5 Alkaloids

More than 12,000 alkaloids have been isolated from the plant kingdom, and this number is increasing exponentially. Based on their structure, alkaloids may be classified as indole, tropane, piperidine, purine, imidazole, pyrrolizidine, pyrrolidine, quinolizidine, and isoquinoline alkaloids [73–75]. They are well known for their pharmacological activities such as antioxidant [76,77] antidiabetic [76], antimicrobial [77], anti-inflammatory [78], anticancer [79], and amoebicidal properties [80]. The structures of various alkaloids isolated from *Casimiroa* and their biological activities are described in the following section. Genus *Casimiroa* are famous for different alkaloids like furoquinoline, quinolinone, and quinolone. In 1999, seven active alkaloids, proline (**20**), *N*-methylproline (**21**), *N*-monomethylhistamine (**22**), *N*,*N*-dimethylhistamine (**23**), synephrine acetonide (**24**), γ-amino-butyric acid (**25**), and synephrine acetonide, (**26**) have been derived from the seeds of *C. edulis* (data not reported) [35]. Iriarte et al. and Ito et al. found the presence of 4-methoxy-1-methyl-2(1*H*)-quinolinone (**27**), edulitine (**28**) (no NMR data), casimiroin (**29**), dictamnine (**30**), γ-Fagarine (**31**), and skimmianine (**32**) from various parts (seeds, bark, trunk, and root bark) of *C. edulis* [23,24]. A quinolone alkaloid, 1-methyl-2-phenyl-4-quinolone (**33**) was identified from the seeds of *C. tetrameria* [33]. Other researchers reported the presence of quinolone alkaloids: edulein (no NMR data) (**34**), seven quinolinone alkaloids: 5-hydroxy-1-methyl-2-phenyl-4-quinolone (**35**), 5,6-dimethoxy-2-(3-methoxyphenyl)-1*H*-quinolin-4-one (**36**), 5,6-dimethoxy-2-(3,4-dimethoxyphenyl)-1*H*-quinolin-4-one

Table 12: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of quinolinone and quinolone alkaloids isolated from genus *Casimiroa*

Carbon no.	Cp 33 [85]		Cp 35 [24,86]		Cp 36 [28]		Cp 37 [28]		Cp 38 [28]		Cp 39 [27]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
2	154.8	–	155.5	–	164.0	–	163.0	–	161.6	–	164.21	–
3	112.7	6.31	104.6	6.22	112.7	6.74	112.6	6.65	107.7	6.20	113.41	–
3-Propyl	–	–	–	–	–	–	–	–			24.63, 21.92, 13.94	0.96, 1.58, 2.45
4	177.6	–	181.7	–	180.1	–	182.0	–	180.2	–	179.10	–
4a	126.8	–	113.9	–	no data	–	119.0	–	118.0	–	117.31	–
5	126.8	8.51	162.8	–	151.8	–	151.8	–	151.4	–	152.32	–
6	123.8	7.45	110.9	7.48	No data	–	No data	–	149.0	–	152.92	7.81
5-OMe	–	–			62.0	3.88	62.0	3.93	62.0	3.92	61.10	3.83
6-OMe	–	–			57.3	3.88	61.4	3.91	61.8	3.88	–	–
7	132.3	7.73	134.3	7.56	120.9	7.49	121.0	7.37	120.9	7.39	120.94	7.95
8	115.9	7.57	109.8	7.56	115.0	7.56	115.0	7.47	115.0	7.54	115.14	–
8-OMe											59.73	3.79
8a	141.9	–	142.7	–	No data	–	No data	–	No data	–	116.81	–
1′	135.9	–	135.3	–	133.0	–	129.9	–	119.0	–	130.41	–
2′	128.5	7.42	128.9	6.81	118.4	7.57–7.44	116.9	7.18	153.0	–	119.25	7.15
3′	128.8	7.52	128.4	7.69	161.8	–	153.0	–	115.1	6.81	152.92	–
4′	129.6	7.52	129.9	–	131.2	7.13	155.0	–	117.0	7.14	131.12	7.14
5′	128.8	7.52	128.4	–	108.2	7.57–7.44	121.6	7.20	148.3	–	122.4	7.25
6′	128.5	7.42	128.9	7.19	119.6	7.57–7.44	125.6	7.33	153.4	–	126.14	7.31
2′-OMe	–	–	–	–	–	–	–	–	57.4	3.85	–	–
3′-OMe	–	–	–	–	55.9	3.93	57.4	3.85	–	–	56.11	3.71
4′-OMe	–	–	–	–	–	–	56.6	3.85	–	–	–	–
5′-OMe	–	–	–	–	–	–	–	–	57.0	3.81	–	–
6′-OMe	–	–	–	–	–	–	–	–	56.7	3.75	–	–
N-Me	37.3	3.62	37.9	3.60	–	–	–	–	–	–	–	–

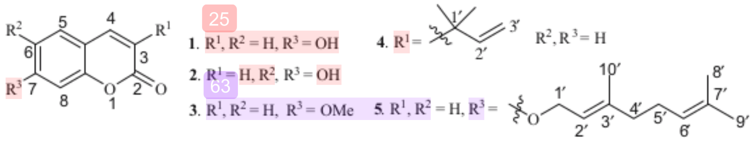


Figure 1: Structures of simple coumarins of *Casimiroa*.

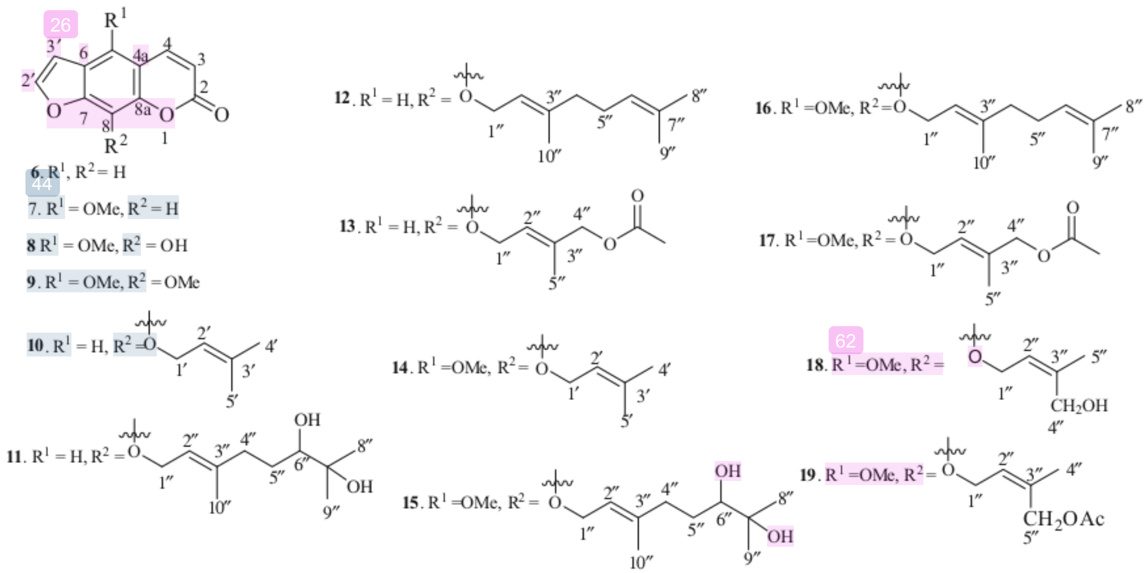


Figure 2: Structures of furanocoumarins from *Casimiroa*.

(**37**), 5,6-dimethoxy-2-(2,5,6-tri-methoxyphenyl)-1*H*-quinolin-4-one (**38**), 5,8-dimethoxy-2-(3′-methoxy-phenyl)-3-propyl-1*H*-quinolin-4-one (**39**), 5,8-dimethoxy-2-(3′,4′-di-methoxy-phenyl)-3-propyl-1*H*-quinolin-4-one (**40**), and 2-(2′-hydroxy-4′-methoxy-phenyl)-5,8-dimethoxy-3-propyl-1*H*-quinolin-4-one (**41**) from the various parts (leaves, fruits, seeds, trunk, and root bark) of *C. edulis* [23,24,27,28]. The chemical structures of various alkaloids are shown in Figures 3–5, and their NMR (^{1}H NMR and ^{13}C NMR) data are presented in Tables 8, 9, 10, 12, and 13.

6 Flavonoids

Flavonoids are a large group of plant metabolites. They are divided into several subgroups. Among them, flavones, flavonols, flavanones, flavanonols, flavanols or catechins, antocyanins, and chalcones are almost always in the plant kingdom. They have been isolated from fruits, nuts seeds, stem, flowers, wine, and other vegetal tissues of large number of plants [87]. Flavonoids are known for their pharmacological properties such as antioxidants [88–90], antibacterial [90], antiviral [91], anti-inflammatory [92,93], antiallergic [93], antidiabetic [94], and anticancer activities [95]. Twenty flavonoids, namely, 6,7-dimethoxyflavone (**42**), 6-hydroxy-5-methoxyflavone (**43**), zapotinin (**44**), 5,6,2′-trimethoxyflavone (**45**), 5,6,3′-trimethoxyflavone (**46**), 5,6,2′,3′-trimethoxyflavone (**47**), 5,7,3′,5′-tetramethoxy-flavone (**48**), 5,6,3′,5′-tetramethoxy-flavone (**49**), zapotin (**50**), zapotinin acetate (**51**), 5,6,2′,3′,4′-pentamethoxyflavone (**52**), 5,6,2′,3′,6′-pentamethoxy-flavone (**53**), 5,6,2′,3′,4′,6′-hexamethoxy-flavone (**54**), 5,6,2′,3′,5′,6′-hexamethoxy-flavone (**55**), 5-methoxyflavone 6-*O*-β-D-glucoside (**56**), quercetin (**57**), quercetin 3-*O*-rutinoside (**58**), kaempferol 3-*O*-rutinoside (**59**), quercetin 3-*O*-glucoside (**60**), and kaempferol 3-O-*glucoside* (**61**) were isolated from various parts (stem bark, leaves, and seeds) of *C. edulis*, *C. pubescens*, Casimiroa *sapota*, and *C. tetrameria*. The structures of flavonoids are shown in Figure 6, and their

Table 13: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of quinolinone and quinolone alkaloids isolated from genus *Casimiroa*

Carbon no.	Cp 40 [27]		Cp 41 [27]	
	δ_C	δ_H	δ_C	δ_H
2	158.79	–	163.9	–
3	113.31	–	113.31	–
3-Propyl	24.63, 21.92, 13.94	0.96, 1.58, 2.45	24.63, 21.92, 13.94	0.96, 1.58, 2.45
4	178.56	–	178.3	–
4a	117.83	–	117.31	–
5	149.77	–	152.32	–
6	145.29	6.88	No data	6.81
5-OMe	61.90	3.98	61.90	3.92
7	147.12	7.95	121.34	7.97
8	114.94	–	114.94	–
8-OMe	56.77	3.97	57.13	3.85
8a	116.51	–	116.81	–
1′	147.79	–	133.4	–
2′	119.61	7.56	119.21	–
3′	No data	–	162.1	7.49
4′	151.781	–	131.12	–
5′	108.14	7.39	108.14	7.29
6′	120.14	7.49	120.14	7.26
2′-OMe	–	–	–	–
3′-OMe	No data	3.93	–	–
4′-OMe	56.77	3.93	56.11	3.85
5′-OMe	–	–	–	–
6′-OMe	–	–	–	–
N-Me	–	–	–	–

NMR (^{1}H NMR and ^{13}C NMR) data are presented in Tables 15–17.

7 *N*-Benzoyltyramide derivatives

Four ***N***-benzoyltyramide derivatives **62–65** (Table 18), were reported from the genus *Casimiroa*. Compounds **62** and **63** contain isopropylidene moiety in their *O*-alkyl side chains. Likewise, compound **62** contains monoterpenic moiety in *O*-alkyl side chain. The structures of *N*-benzoyltyramide derivatives are shown in Figure 7, and their NMR (^{1}H NMR and ^{13}C NMR) data are presented in Table 19.

8 Pharmacological activities

Several pharmacological reports have confirmed the wide variety of biological activities of the genus *Casimiroa*. For example, Mora et al. [16] reported the effect on central nervous system by the extract of hydroalcoholic leaves of *C. edulis*, using different behavioral tests and animal models of depression and anxiety. The extract exhibited sedative and antidepressant properties in rodents. The leaves and seeds extracts of *C. edulis* also showed the anticonvulsant activity *in vivo* [15,17]. Esposito et al. [20] studied the HIV-1 reverse transcriptase-associated activities of the hydroalcoholic extract of *C. edulis* seeds, using HIV-1 RT RDDP assay and HIV-1 RT RNase H assay. The extract exhibited the ability to inhibit both RDDP (IC_{50} 0.27 µg mL^{-1}) and RNase H (IC_{50} 2.0 µg mL^{-1}) activities in a dose-dependent manner. The extract was also displayed dose-dependent cytotoxicity on K562 (CC_{50} 3.1 mg mL^{-1}) cell line. The antimutagenic activity of several compounds (**9**, **11**, **14**, **15**, **27**, **29**, **31**, **35**, **45**, and **48**) were evaluated against *Salmonella typhimurium* strain TM677, using the antimutagenicity assay. Compounds **15** and **29** were found to have the most significant antimutagenic activity against *S. typhimurium* strain TM677. Compounds **29** and **45** were also inhibited the formation of DMBA-induced preneoplastic lesions in the mouse mammary gland [24]. Awaad et al. [25] reported not only the antimicrobial activity of ethyl acetate, butanol, ether, and chloroform fractions but also anticoagulant activity of ethanol extract and

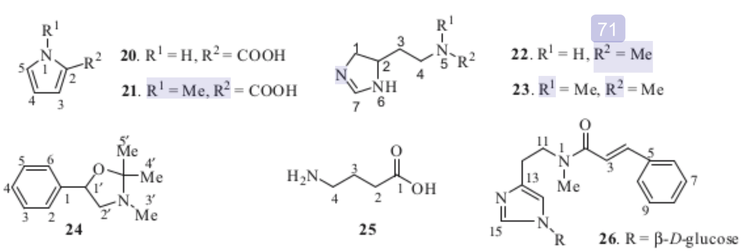


Figure 3: Structures of alkaloids from *Casimiroa*.

Table 14: Pharmacological properties of flavonoids obtained from *Casimiroa* species

Compound (Cp)	Biological activities	Plant	Part used	Ref.
6,7-Dimethoxyflavone (**42**)	Antioxidant & antidiabetic	*C. edulis*	Stem bark	[37]
6-Hydroxy-5-methoxyflavone (**43**)	Antioxidant	*C. edulis*	Seeds	[26]
Zapotinin (**44**)	—	*C. edulis*	Seeds	[66,96]
5,6,2′-Trimethoxyflavone (**45**)	Antimutagenic & solid tumor selective cytotoxicity	*C. edulis* & *C. tetrameria*	Seeds	[24,29,37]
5,6,3′-Trimethoxyflavone (**46**)	—	*C. sapota*	Leaves	[97]
5,6,2′,3′-Trimethoxyflavone (**47**)	—	*C. sapota*	Leaves	[97]
5,7,3′,5′-Tetramethoxy-flavone (**48**)	Solid tumor selective cytotoxicity	*C. edulis* & *C. tetrameria*	Seeds	[33]
5,6,3′,5′-Tetramethoxy-flavone (**49**)	—	*C. tetrameria*	Seeds	[98]
Zapotin (**50**)	Antimutagenic & solid tumor selective cytotoxicity	*C. edulis* & *C. pubescens*	Seeds	[24,33]
Zapotinin acetate (**51**)	—	*C. edulis*	Seeds	[66,96]
5,6,2′,3′,4′-Pentamethoxyflavone (**52**)	Vasodilation & radical scavenging	*C. pubescens*, C. edulis & *C. sapota*	Seeds	[32]
5,6,2′,3′,6′-Pentamethoxy-flavone (**53**)	—	*C. tetrameria*	Leaves	[30]
5,6,2′,3′,4′,6′-Hexamethoxy-flavone (**54**)	—	*C. tetrameria*	Leaves	[98]
5,6,2′,3′,5′,6′-Hexamethoxy-flavone (**55**)	—	*C. tetrameria* & *C. edulis*	Leaves	[29,30]
5-Methoxyflavone 6-*O*-β-D-glucoside (**56**)	Antioxidant	*C. edulis*	Leaves	[26]
Quercetin (**57**)	Antioxidant	*C. edulis*	Leaves	[26]
Quercetin 3-*O*-rutinoside (**58**)	Antioxidant	*C. edulis*	Leaves	[26]
Kaempferol 3-*O*-rutinoside (**59**)	—	*C. tetrameria*	Leaves	[98]
Quercetin 3-*O*-glucoside (**60**)	—	*C. tetrameria*	Leaves	[98]
Kaempferol 3-*O*-glucoside (**61**)	—	*C. tetrameria*	Leaves	[98]

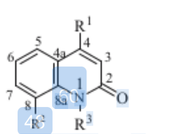
Table 15: [13]C and [1]H NMR chemical shift data (δ, ppm) of flavonoids isolated from genus *Casimiroa*

Carbon no.	Cp 42 [37]		Cp 43 [26]		Cp 45[38]		Cp 46 [66]		Cp 47 [97]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
2	161.6	–	164.18	–	159.1	–	ND	–	ND	–
3		6.69	108.19	6.75	113.1	6.98	ND	6.63	11.25	6.82
4	178.0	–	180. 29	–	178.4	–	ND	–	ND	–
4a	119.3	–	119.48	–	119.1	–	ND	–	ND	–
5	113.4	7.32	149.10	–	158.0	–	ND	–	ND	–
6	148.0	–	148.57	–	149.7	–	ND	–	147.29	–
7	150.0	–	125.63	7.72	113.4	7.30	ND	7.30	7.58	119.53
8	119.1	7.32	115.28	7.45	119.2	7.27	ND	7.30	113.65	7.45
8a	151.6	–	154.19	–	151.9	–	ND	–	150.11	–
5-OMe	–	–	62.46	3.90	57.3	3.93	ND	3.99	60.00	3.94
6-OMe	57.2	3.94	–	–	55.7	3.93	ND	3.92	55.97	3.96
7-OMe	61.9	3.98	–	–	–	–	ND	–	–	
1′	131.7	–	132.49	–	120.8	–	ND		ND	–
2′	126.1	7.89	127.39	7.98	147.9	–	ND	7.42	ND	–
3′	129.0	7.51	130.26	7.54	111.7	7.03	ND	–	ND	–
4′	131.4	7.51	133.1	7.54	132.2	7.46	ND	7.03	115.46	7.25
5′	129.0	7.51	130.26	7.54	120.7	7.09	ND	7.42	124.28	7.24
6′	126.1	7.89	127.39	7.98	129.1	7.85	ND	7.42	120.23	7.39
2′-OMe	–	–	–	–	61.9	3.98	ND	–	60.66	3.92
3′-OMe	–	–	–	–	–	–		3.87	55.2	3.91
4′-OMe	–	–	–	–	–	–	–	–	–	–
5′-OMe	–	–	–	–	–	–	–	–	–	–
6′-OMe	–	–	–	–	–	–	–	–	–	–
Acetyl(C=O)	–	–	–	–	–	–	–	–	–	–
Acetyl-Me	–	–	–	–	–	–	–	–	–	–

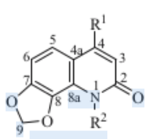
ND = no data reported.

Table 16: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of flavonoids isolated from genus *Casimiroa*

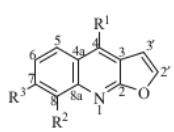
Carbon no.	Cp 50 [99]		Cp 52 [32]		Cp 53 [30]		Cp 55 [30]		Cp 56 [26]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
2	158.9		160.6	–	158.5	–	158.6	–	164.18	–
3	115.2	6.26	110.9	6.84	115.2	6.27	114.5	6.29	108.19	6.75
4	178.2	–	178.4	–	178.0	–	177.8	–	180.29	–
4a	119.4	–	118.9	–	119.5	–	119.5	–	119.48	–
5	148.0	–	147.8	–	148.6	–	148.1	–	149.10	–
6	149.6	–	149.9	–	149.8	–	149.9	–	149.28	–
7	119.1	7.28	119.3	7.30	113.7	7.26	113.6	7.26	125.63	7.72
8	113.7	7.20	113.3	7.25	119.1	7.18	119.2	7.17	115.28	7.45
8a	152.7	–	151.7	–	152.6	–	152.4	–	154.19	–
5-OMe	61.8	3.98	56.2	3.98	62.0	3.97	62.0	3.98	62.5	3.9
6-OMe	57.3	3.92	61.3	3.93	57.4	3.91	57.3	3.91	–	–
1′	111.4	–	118.5	–	–	–	101.7	–	132.49	–
2′	158.6	–	153.3	–	147.15	–	140.9	–	127.46	δ 7.98
3′	104.0	6.63	142.7	–	132.1	–	149.2	–	130.28	7.54
4′	132.0	7.39	156.5	–	115.0	6.98	114.5	6.67	133.04	δ 7.54
5′	104.0	6.63	107.4	6.79	106.3	6.65	149.2	–	130.28	7.54
6′	158.6	–	124.2	7.5	151.8		140.9	–	127.46	7.98
2′-OMe	56.0	3.79	57.2	3.95	61.6	3.83	61.8	3.75	–	–
3′-OMe	–	–	62.0	3.91	56.7	3.85	56.7	3.88	–	–
4′-OMe	–	–	61.0	3.94	–	–	–	–	–	–
5′-OMe	–	–	–	–	–	–	56.7	3.88	–	–
6′-OMe	56.0	3.79	61.3	3.93	57.4	3.91	57.3	3.91	–	–
Acetyl(C=O)	–	–	–	–	–	–	–	–	–	–
Acetyl-Me	–	–	–	–	–	–	–	–	–	–
1″	–	–	–	–	–	–	–	–	103.38	4.96
2″	–	–	–	–	–	–	–	–	75.05	–
3″	–	–	–	–	–	–	–	–	78.11	–
4″	–	–	–	–	–	–	–	–	71.34	3–3.9
5″	–	–	–	–	–	–	–	–	78.4	–
6″	–	–	–	–	–	–	–	–	62.74	–



27. R^1 = OMe, R^2 = H, R^3 = Me
28. R^1, R^2 = OMe, R^3 = H

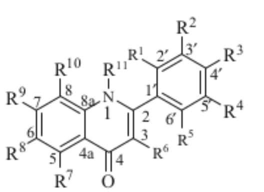


29. R^1 = OMe, R^2 = Me



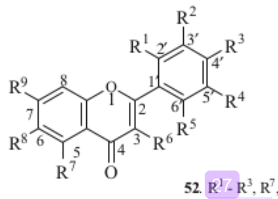
30. R^1 = OMe, R^2, R^3 = H
31. R^1, R^2 = OMe, R^3 = H
32. R^1-R^3 = OMe

Figure 4: Structures of quinolone alkaloids from *Casimiroa*.



33. R^1 - R^{10} = H, R^{11} = Me
34. R^1-R^8 = H, R^9 = OMe, R^{10} = H, R^{11} = Me
35. R^1 - R^6, R^8-R^{10} = H, R^7 = OH, R^{11} = Me
36. R^1, R^3 - R^6, R^9 - R^{11} = H, R^2, R^7, R^8 = OMe
37. R^1, R^4, R^5, R^9 - R^{11} = H, R^2, R^3, R^7, R^8 = OMe
38. R^1, R^4, R^5, R^7, R^8 = OMe, R^2, R^3, R^6, R^9 - R^{11} = H
39. R^1, R^3 - R^5, R^8, R^9, R^{11} = H, R^2, R^7, R^{10} = OMe, R^6 = -C_3H_7
40. R^1, R^4, R^5, R^8, R^9, R^{11} = H, R^2, R^3, R^7, R^{10} = OMe, R^6 = -C_3H_7
41. R^1 = OH, R^2, R^4, R^5, R^8, R^9, R^{11} = H, R^3, R^7, R^{10} = OMe, R^6 = -C_3H_7

Figure 5: Structures of quinolinone and quinolone alkaloids from *Casimiroa*.



42. R^1 - R^7 = H, R^8, R^9 = OMe
43. R^1 - R^6, R^9 = H, R^7 = OMe, R^8 = OH
44. R^1, R^5, R^8 = OMe, R^2 - R^4, R^6, R^9 = H, R^7 = OH
45. R^1 - R^4, R^6, R^9 = H, R^5, R^7, R^8 = OMe
46. R^1, R^3, R^5, R^6, R^8 = H, R^2, R^4, R^7, R^9 = OMe
47. R^7, R^8, R^2 = OMe, R^1, R^3-R^6, R^9 = H
48. R^1, R^2, R^7, R^8 = OMe, R^3-R^6, R^9 = H
49. R^1, R^3. R^5. R^6. R^9 = H, R^2, R^4, R^7, R^8 = OMe
50. R^1, R^5, R^7, R^8 = OMe, R^2, R^3, R^4, R^6, R^9 = H
51. R^1, R^5, R^8 = OMe, R^2 - R^4, R^6, R^9 = H, R^7 = OAcO
52. R^1 - R^3, R^7, R^8 = OMe, R^4 - R^6, R^9 = H
53. R^1, R^2, R^5, R^7, R^8 = OMe, R^3, R^4, R^6, R^9 = H
54. R^1 - R^3, R^5, R^7, R^8 = OMe, R^4, R^6, R^9 = H
55. R^1, R^2, R^4, R^5, R^7, R^8 = OMe, R^3, R^6, R^9 = H
56. R^1 - R^6, R^9 = H, R^7 = OMe
57. R^1, R^4, R^5, R^8 = H, R^2, R^3, R^6, R^7, R^9 = OH
58. R^1, R^4, R^5, R^8 = H, R^2, R^3, R^7, R^9 = OH, R^6 = *O*-rhamnose glucose
59. R^1 - R^2, R^4, R^5, R^8 = H, R^3, R^7, R^9 = OH, R^6 = *O*-rhamnose glucose
60. R^1, R^4, R^5, R^8 = H, R^2, R^3, R^7, R^9 = OH, R^6 = *O*-glucoside
61. R^1, R^2, R^4, R^5, R^8 = H, R^3, R^7, R^9 = OH, R^6 = O-glucoside

Figure 6: Structures of flavonoids from genus *Casimiroa*.

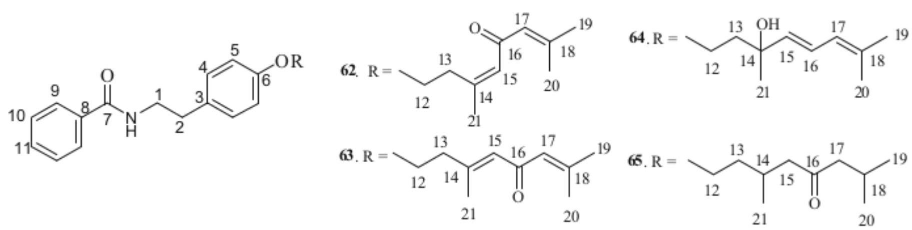


Figure 7: Structures of *N*-benzoyltyramide derivatives from *Casimiroa*.

compounds **1**, **2**, **6**, and **10** from the leaves of *C. edulis*. Another important study was performed on the antioxidant activity of fractions and isolated compounds (**43**, **54**, **55**, and **56**) from leaves of *C. edulis*. Ethanol fraction was exhibited the more potent antioxidant activity (842 µM Trolox equivalents/g dry weight) [26]. According to the study by Awaad et al. [27], compounds **38**–**39** and fruit extracts of *C. edulis* were tested for the antihypertensive activity using male dogs. All compounds showed the antihypertensive activity at doses of 50, 100, 200, and 300 mg/kg, and the ethanolic and total alkaloids (in chloroform) extracts were found to possess important antihypertensive properties at doses of 500 and 200 mg/kg, respectively. Nagai et al. [29] reported the functions of glucose and lipid metabolism activities with 3T3-L1 adipocytes on two furocoumarins (**13** and **17**) and two polymethoxyflavones (**45** and **53**) from leaves of *C. edulis*. It was clear that the addition of furanocoumarin increased the glucose uptake and lipid accumulation in 3T3-L1 adipocyte. Bertin et al. [31] reported vasodilation and radical-scavenging activity of imperatorin and selected coumarinic and flavonoid compounds (**3**, **10**, **12**, and **50**) from seeds of *C. edulis* and *C. pubescens*. Ya-ming et al. [33] evaluated solid tumor selective cytotoxicity of extract, fractions, and compounds (**19**, **33**, **45**, **46**, **48**, **61**, and **62**) from *C. tetrameria*. Compounds **48**, **61**, and **62** were active against solid tumor cell line C38 and a leukemia cell line L1210. Cardiovascular activities for compounds **20**–**27** were also reported [35]. Ubaldo-suarez et al. [36] evaluated antidepressant-like effect of hexane, ethyl acetate, and methanol roots extracts of *C. pubescens*, using the forced swim test. The result showed antidepressant-like activity on hexane extract. Further studies reported antidiabetic and antioxidant activities of compounds **7**, **9**, **42**, and **45**, isolated from *C. edulis* using the DPPH radical scavenging assay and the yeast α-glucosidase assay [37,38]. Moreover, the leaves, seeds, and nonedible fruit's parts extracts of *C. edulis* have been studied for their biological effects, including antihypertensive, vasorelaxant, antioxidant, anti-inflammatory, antitumor, relaxant, and contractile effect *in vitro* [18,103,104]. Landaverde et al. [105] noted

Table 17: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of flavonoids isolated from genus *Casimiroa*

Carbon no.	Cp 57 [100]		Cp 58 [101]		Cp 59 [101]		Cp 60 [102]		Cp 61 [102]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
2	147.8	–	158.22	–	155.98	–	158.4	–	156.4	–
3	136.8	9.44	134.52	–	134.58	–	135.6	–	133.3	–
4	176.9	–	178.39	–	177.23	–	179.1	–	177.4	–
4a	103.9	–	105.32	–	104.79	–	105.7	–	104.1	–
5	161.9	12.54	162.48	–	162.04	–	163.0	–	161.3	–
6	98.8	6.22	99.72	6.10	98.88	6.22	98.0	6.16	99.1	6.30
7	165.0	10.85	166.58	–	163.31	–	168.4	–	164.2	–
8	94.0	6.44	94.90	6.28	93.98	6.33	95.6	6.38	93.8	6.50
8a	157.4	–	158.91	–	156.82	–	160.0	–	156.5	–
1′	123.1	–	122.77	–	121.39	–	121.2	–	121.0	–
2′	115.7	7.71	117.37	7.64	130.76	8.19	115.9	7.47	131.0	8.05
3′	146.2	–	144.32	–	113.40	6.92	146.5	–	115.2	6.95
4′	148.7	–	150.23	–	160.92	–	151.4	–	160.0	–
5′	116.2	6.92	115.46	6.85	114.87	6.92	116.9	6.79	115.2	6.95
6′	120.6	7.57	122.47	7.63	131.03	8.19	121.3	7.64	131.0	8.05
1″	–	–	103.63	4.96	102.11	5.02	104.4	ND	101.2	5.48
2″	–	–	74.64	–	74.83	–	75.7	ND	74.3	3.32
3″	–	–	77.81	–	75.48	–	78.1	ND	76.5	3.55
4″	–	–	71.12	3.20–3.90	69.23	3.15–3.90	71.2	ND	69.9	3.20
5″	–	–	78.09	–	77.65	–	78.4	ND	77.6	3.21
6″	–	–	68.37	–	67.08	–	62.6	ND	60.9	3.58, 3.72
1‴	–	–	101.92	4.50	100.10	4.45	–	–	–	–
2‴	–	–	71.32	–	70.89	–	–	–	–	–
3‴	–	–	72.13	–	72.23	–	–	–	–	–
4″	–	–	73.73	3.20–3.90	73.46	3.20–3.90	–	–	–	–
5‴	–	–	68.91	–	67.88	–	–	–	–	–
6‴	–	–	18.84	1.12	18.12	1.09	–	–	–	–
3-OH	–	–	–	–	–	–	–	–	–	–
5-OH	–	–	–	–	–	–	–	–	–	–
7-OH	–	–	–	–	–	–	–	–	–	–
3′-OH	–	–	–	–	–	–	–	–	–	–
4′-OH	–	–	–	–	–	–	–	–	–	–

ND = no data reported.

Table 18: Pharmacological properties of benzoyltyramide derivatives isolated from *Casimiroa* species

Compound (Cp)	Biological activities	Plant	Part used	Ref.
Pubesamide A (**62**)	Solid tumor selective cytotoxicity	*C. tetrameria* & *C. pubescens*	Seeds	[33,34]
Pubesamide B (**63**)	Solid tumor selective cytotoxicity	*C. tetrameria* & *C. pubescens*	Seeds	[33,34]
Pubesamide C (**64**)	–	*C. pubescens*	Seeds	[34]
Tetrahydropubesamide A (**65**)	–	*C. pubescens*	Seeds	[34]

Table 19: ^{13}C and ^{1}H NMR chemical shift data (δ, ppm) of *N*-benzoyltyramide derivatives isolated from genus *Casimiroa*

Atom no.	Cp 61 [34]		Cp 62 [34]		Cp 63 [34]		Cp 64 [34]	
	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H	δ_C	δ_H
1	41.3	3.69	41.3	3.69	41.3	3.67	41.2	3.69
2	34.8	2.87	34.8	2.86	34.8	2.86	34.8	2.87
3	131.2	–	130.7	–	131.3	–	130.8	–
4	129.8	7.14	129.7	7.13	129.8	7.14	129.7	7.15
5	114.9	6.85	114.8	6.86	114.9	6.85	114.7	6.85
6	157.5	–	157.7	–	157.2	–	157.7	–
7	167.4	–	167.4	–	167.4	–	167.4	–
8	134.7	–	134.7	–	134.6	–	134.7	–
9	126.8	7.69	126.1	7.68	126.8	7.68	126.8	7.69
10	128.5	7.45	128.5	7.45	128.5	7.41	128.5	7.38
11	131.4	7.38	131.4	7.41	131.4	7.47	131.6	7.45
12	65.9	4.09	67.2	4.16	65.4	4.12	66.0	3.97
13a	40.6	2.59	33.7	3.06	40.9	2.14	36.0	1.78
13b	–	–	–	–	40.9	1.97	36.0	1.67
14	154.9	–	155.0	–	72.7	–	26.4	2.26
15	126.2	6.08	127.4	6.08	136.6	5.63	50.6	2.41
16	191.4	–	190.8	–	124.5	6.52	210.4	–
17	127.4	6.13	126.0	6.13	124.3	5.82	52.3	2.26
18	153.0	–	153.0	–	135.5	–	24.5	2.15
19	27.8	1.88	27.8	1.89	18.3	1.73	22.6	0.90
20	20.6	2.17	20.6	2.15	26.0	1.76	22.6	0.91
21	19.3	2.22	26.8	2.01	29.0	1.37	19.9	0.97

that essential oils extracted from *C. pringlei* displayed significant sedative and anxiolytic properties in rats. However, there is still a lack of biological and other phytochemical research to prove medicinal uses of genus *Casimiroa* like *Casimiroa watsonii*, *Casimiroa tomentosa*, *C. sapota* Var. Villosa, *Casimiroa calderoniae*, *Casimiroa dura*, *Casimiroa emarginata*, *Casimiroa greggii*, and *Casimiroa microcarpa*.

9 Concluding remarks

Casimiroa genus is a rich of diverse plant metabolites, with important biological activities. Their potential as drug leads is yet to be explored. Several *Casimiroa* species have not yet been chemically studied. Therefore, it is necessary to carry out these studies to contribute to the taxonomic classification and medicinal chemistry. In this article, the emphasis has been on the NMR data of compounds obtained from the genus, and pharmaceutically most of these compounds were reported in 1968s, and during that time, the data were either incomplete or unavailable. In this review, we have presented the NMR data and its description of compounds isolated from the genus *Casimiroa*. In addition, the information concerning different skeletons of the compounds is also provided.

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